HALL & ASSOCIATES

Suite 701
1620 I Street, NW
Washington, DC 20006-4033
Telephone: (202) 463-1166 Web: http://www.hall-associates.com Fax: (202) 463-4207

Reply to E-mail:
jhall@hall-associates.com

December 23, 2014

VIA U.S. FIRST-CLASS MAIL

RECEIVED
EPA REGION III
DEC 30 2014
OFC. OF STANDARDS, ASSESSMENT & TMDLs (3WP30)

Mr. Jon Capacasa
Director
Water Protection Division
EPA Region III
1650 Arch Street
Philadelphia, PA 19103-2029

Mr. Lee McDonnell
Director for the Bureau of Point and Non-Point Source Management
Pennsylvania Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101

RE: New Information Regarding Validity and/or Need for the Indian Creek Nutrient <u>TMDL – Request for TMDL Reconsideration</u>

Mr. Capacasa and Mr. McDonnell:

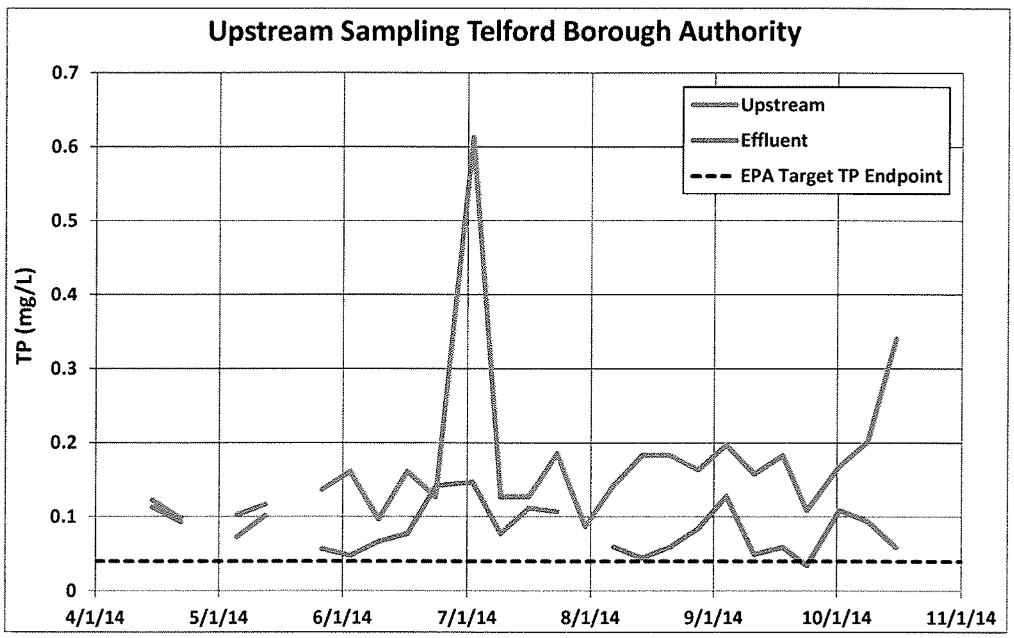
On behalf of the Telford Borough Authority ("Telford"), please see the accompanying new data and information regarding the site-specific conditions in Indian Creek and the need to revise the currently adopted nutrient TMDL for Indian Creek. As you are aware, attaining the phosphorus targets set forth in the TMDL (40 μg/l) would cause a significant financial impact on Telford and the other regulated communities on the Indian Creek watershed. Moreover, the communities have repeatedly raised the concern that meaningful ecological improvements will not result from these expenditures. Due to these concerns regarding the scientific validity of the TMDL, Telford has conducted additional literature research regarding the ability to control periphyton growth in small streams as well as a site-specific evaluation to determine if the Authority's recent, dramatic TP reductions had any effect on periphyton growth. This body of information, never before considered by either EPA or DEP, confirms, to a scientific certainty, that the adopted TMDL TP reductions will be ineffective in addressing periphyton growth in this system. The research does, however, indicate a clear path forward for system restoration. The research verifies that light limitations (via, *e.g.*, canopy restoration or stream bank improvement) can be an effective tool to limit excessive plant growth. To that end, it is our understanding that the Region and the Department are currently discussing an integrated watershed planning "settlement" that will alleviate the need for Telford to further reduce its nutrient load to the targets established in the TMDL. As noted previously, the Authority would participate in such efforts as a more productive expenditure of local resources.

Please consider this submission a formal request to reconsider and amend the TMDL as well as the Section 303(d) listings based on new information showing the TMDL endpoints and requirements are misplaced.

New Information Justifying TMDL and Section 303(d) List Amendment

The following constitutes the new scientific information regarding the efficacy of TP reductions to achieve periphyton growth reduction as expressed in the 2008 Indian Creek Nutrient TMDL.

- Site-specific total phosphorus (TP) data collected upstream of Telford's discharge and from the Telford's effluent confirming downstream water quality is better than upstream water quality.



Conclusion: *Concentrations of TP are higher in the background (upstream) sections of Indian Creek than they are in Telford's discharge itself. TP at the upstream station averaged <0.170 mg/L while the Telford effluent averaged <0.085 mg/L. Thus, it is apparent that a 40 µg/l instream TP concentration cannot be achieved in this system and that background TP levels are elevated as previously stated by the Authority.*

- The site-specific Indian Creek report done by Kleinfelder, Inc. in the 2014 growing season analyzing TP and periphyton data. *See attached*, Ex. 1.

<u>Conclusion:</u> *Excessive plant growth is occurring in Indian Creek regardless of TP concentrations and Telford's wastewater treatment plant reductions; the chlorophyll-a level has no relationship to TP concentrations in Indian Creek. During the 9/24/14 periphyton survey, periphyton levels of 300-335 mg/m^2 chl-a were observed in a range of 0.10-0.24 mg/L TP. At the remaining survey sites, higher periphyton levels between 490-825 mg/m^2 chl-a were observed in a slightly lower range of 0.06-0.18 mg/L TP. Periphyton remained very high on the unnamed tributary where the, now discontinued, Pilgrim's Pride discharge had been located. Periphyton reductions are not occurring as predicted by the TetraTech modeling, confirming that model is not properly calibrated. Even zero discharge cannot control periphyton growth.*

Chlorophyll-a levels are affected by the percentage of canopy. The three periphyton survey samples at 0% unshaded sites averaged 372 mg/m^2 chl-a while the three survey samples at sites of at least 70% unshaded averaged 616 mg/m^2.

- Numerous scientific studies confirm that periphyton control via TP reduction is impossible, except at extremely low levels of TP that are not attainable in this system (less than 10- 20 μg/l of soluble reactive phosphorus). *See attached* Ex. 2, Literature Synopsis; Ex. 3, WE&T Article, August 2014.

<u>Conclusion:</u> *The studies confirm that light limitation is the only viable means of controlling periphyton growth in systems such as these. Even if the 40 ug/l TP goal of the TMDL was met, the excessive algae would continue unabated; other improvements (i.e., canopy restoration) will be necessary to improve the conditions in Indian Creek. Moreover, if such habitat restoration is completed, there is no need to reduce TP.*

In summary, Telford believes that this new information confirms, to a scientific certainty, that the 40 μg/l instream TP target in the Indian Creek TMDL (1) is unachievable given the background concentrations of TP, and (2) would not eliminate the impairments in Indian Creek, even if it were achieved. The literature confirms that it is only through light limitation, the presence of grazers and periodic scouring events that periphyton growth is reduced in small stream systems such as Indian Creek. In fact, we would expect that extensive stormwater controls, proposed by EPA, *will cause greater periphyton growth to occur* in this system by reducing the number of scouring events and allowing filamentous growth to persist. That is, this new information not only confirms that the TMDL's present approach will not just misdirect local resources on an ineffective remedy, it will, in the end, most likely cause more harm than good.

In light of this new information and Pennsylvania's law recognizing that waterbodies impaired due to natural/background conditions do not need a TMDL, Telford requests that the Region and Department reconsider the 303(d) impairment listing and the nutrient TMDL for Indian Creek. In the interim, Telford requests that the TMDL be deferred and/or withdrawn in lieu of habitat, canopy, and riparian zone restoration.

Respectfully,

John C. Hall

Enclosures

Exhibit 1

TECHNICAL REPORT

INDIAN CREEK WATERSHED PERIPHYTON DENSITY AND PHOSPHORUS CONCENTRATION SURVEY

TELFORD BOROUGH AUTHORITY
BUCKS AND MONTGOMERY COUNTIES, PA
NPDES NO. PA0036978

DECEMBER 2014

Research Park, 321 Wall Street, Princeton, NJ 08540 p | 609.924.8821 f | 609.924.8831

PRI14M11321

Table of Contents

PAGE

List of Tables

List of Figures

List of Appendices

I. PROJECT DESCRIPTION

The Telford Borough Authority (TBA) wastewater treatment plant (WWTP), located at 109 Telford Pike in Telford, Pennsylvania, is currently authorized to discharge 1.1 million gallons per day (MGD) of treated sanitary wastewater to Indian Creek, in accordance with the requirements of its National Pollutant Discharge Elimination System (NPDES) permit (#PA0036978). A periphyton density and phosphorus concentration survey was performed at multiple locations in the Indian Creek watershed in order to characterize the influence of phosphorus and canopy cover on periphyton density.

An initial visit to each sampling location was performed on September 11, 2014 to confirm access, identify the exact location using a global position system (GPS), and establish any necessary safety protocols. Actual sampling was performed by two Kleinfelder sampling engineers on September 24, 2014. The survey was performed during a single sampling event during conditions that were optimal for assessing nutrient impacts. Specifically, surface flows at the nearest relevant continuous stream flow gage (USGS 01472810 East Branch Perkiomen Creek near Schwenksville, PA) did not show any runoff flows during the 18 days prior to the sampling event. Furthermore, the nearby precipitation gage at the airport in Quakertown, PA (KUKT) did not record a single rain event greater than one-half inch in the 59 days prior to the sampling event.

Sampling was performed at six (6) sampling locations within the Indian Creek watershed, as described below and shown in Figure 1. Locations were selected to represent a variety of phosphorus and shade conditions (see site location photos in Appendix A). Locations were intentionally selected such that conditions were either 100% shaded or 100% unshaded, when such conditions existed within the desired stream segment. The degree of shade was measured in the field as "Percent Unshaded" by facing south and approximating the percentage of view to sky (to the nearest 10%) along a sunrise-sunset parabola.

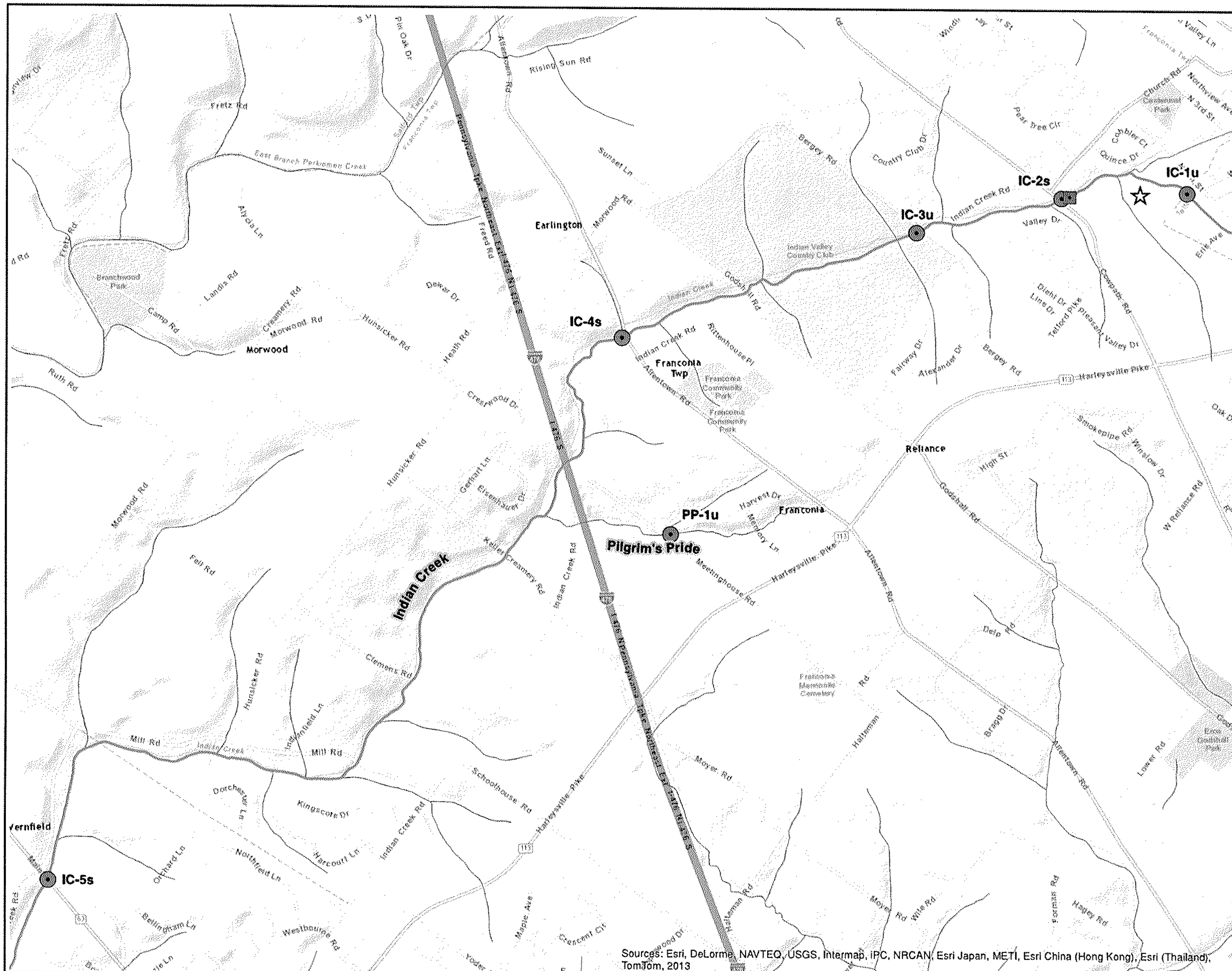


Figure 1
Sampling Map

Telford Borough Authority WWTP
NPDES #PA0036978
Indian Creek Periphyton and Phosphorus Study

- Sampling Location
- Discharge Location
- Telford Borough WWTP
- Indian Creek
- Streams

2014 ESRI World Street Map
2002 NHD Streams

PROJECT NO.:	6496
DRAWN:	September 2014
DRAWN BY:	ELD
CHECKED BY:	TWA
FILE NAME:	S:\6496\GIS\6496_Survey Map.mxd

0 1,500 3,000
Feet

KLEINFELDER
Bright People. Right Solutions.
321 Wall Street, Princeton, NJ 08540
Tel: 609-924-8821 www.kleinfelder.com

Sampling Locations

IC-1u: Indian Creek approximately 75 feet downstream of West Broad Street in Telford. This location is approximately 2,000 feet upstream of the TBA WWTP outfall, and mostly unshaded at the point where sampling was performed.

IC-2s: Indian Creek immediately upstream of Cowpath Road in Franconia. This location is 140 feet downstream of the TBA WWTP outfall, and shaded at the point where sampling was performed.

IC-3u: Indian Creek immediately downstream of Bergey Road in Franconia. This location is approximately 0.5 miles downstream of the TBA WWTP outfall, and unshaded at the point where sampling was performed.

IC-4s: Indian Creek immediately downstream of Allentown Road in Franconia. This location is approximately 1.5 miles downstream of the TBA WWTP outfall, and shaded at the point where sampling was performed.

IC-5s: Indian Creek immediately upstream of Route 63 (Main Street) in Upper Salford. This location is approximately 4.5 miles downstream of the TBA WWTP outfall, and shaded at the point where sampling was performed.

PP-1u: Pilgrims Pride tributary immediately downstream of Meetinghouse Road in Franconia. This location is upstream of any point source influence, and unshaded at the point where sampling was performed.

The GPS latitudes and longitudes for each sampling location, as well as the TBA WWTP outfall are provided in Table 1 below.

Table 1: GPS Locations

Site	Latitude	Longitude
IC-1u	40.32205065052	-75.33801541442
IC-2s	40.32208450619	-75.34517408883
IC-3u	40.32062650000	-75.35352710000
IC-4s	40.31634510000	-75.37046690000
IC-5s	40.29299762841	-75.40395131075
Outfall	40.32201460000	-75.34468710000
PP-1U	40.30765140000	-75.36798970000

Benthic periphyton density and instream phosphorus concentration were measured at each sampling location, in accordance with the quality assurance procedures described in Section III.

- Kleinfelder field staff collected substrate (rock) samples at each location. Periphyton material was scraped by Kleinfelder staff in the field, and the algal slurries were delivered to QC Laboratories for chl-a analyses.

- Kleinfelder field staff collected a single water quality sample at each location and transported the samples to QC Laboratories for total phosphorus analyses.

II. PROFESSIONAL QUALIFICATIONS

Kleinfelder is an employee-owned engineering, architecture, and science consulting firm providing solutions to meet our world's complex infrastructure and natural resource challenges. Kleinfelder's Princeton Office specializes in helping clients overcome technical and regulatory challenges relating to water resources. Science and engineering professionals at this office have been performing nutrient impact studies, including chemical and biological assessments, for more than 25 years. Kleinfelder served as the prime contractor for the Rutgers University New Jersey EcoComplex in developing diagnostic modeling and assessment tools to address nutrient impairments throughout the entire non-tidal Passaic River and Raritan River Basins, as well as nutrient impact characterization studies of the Rancocas Creek and Pennsauken Creek watersheds. Kleinfelder is well known for the depth of experience it brings to watershed characterization and assessment studies involving nutrients. Additional information regarding the capabilities of the firm can be found here: http://www.kleinfelder.com/index.cfm/services/water-science-engineering/surface-water-planning-analysis/. Three key staff were involved in this sampling project:

- James F. Cosgrove, Jr., P.E. – Vice President / Principal. Jim Cosgrove has more than 25 years of private consulting experience, and is a recognized expert in the fields of water quality monitoring and modeling, watershed management, and litigation support. Mr. Cosgrove is a Professional Engineer; he earned his B.S. in Civil Engineering from Lafayette College and his M.E. in Environmental and Water Resource Systems Engineering from Cornell University. Mr. Cosgrove provided overall quality and project management.

- Thomas Amidon, CLP – Principal Water Resources Scientist. Tom Amidon has over twenty years of experience, including ten years as a research scientist in the New Jersey Department of Environmental Protection, and ten years of private consulting. His areas of expertise include surface water quality studies, watershed management, and environmental impact assessment. Mr. Amidon is a nationally Certified Lake Professional, and was appointed by the Commissioner to the New Jersey DEP Science Advisory Board's Water Quality/Quantity Committee and Nutrient Work Group. He earned his B.S. in Biology from the

Pennsylvania State University and his M.S. in Engineering Science from the State University of New York at Buffalo. Mr. Amidon developed a periphyton density and phosphorus concentration survey that addresses the technical and regulatory challenges associated with the project.

- Joseph (JJ) Schwarz – Senior Staff Engineer. Mr. Schwarz has a broad background in environmental engineering, with extensive experience in field sampling and nutrient impairment studies. He manages Kleinfelder's laboratory and acts as our Quality Assurance Officer. Mr. Schwarz graduated from the University of Notre Dame with a B.S. in Engineering and Environmental Sciences and later received a Master of Engineering degree from Cornell University in Systems Engineering. Mr Schwarz performed the field sampling relating to this project.

III. QUALITY ASSURANCE PROCEDURES

The following quality assurance procedures and methodology were applied to the sample collection and analyses conducted for this study.

Temporal Aspects

Samples were collected at each location during a single sampling event. Sampling was targeted between May and October during dry weather, low-flow conditions, and at a minimum of fourteen days after a rain event of at least 0.5 inches of precipitation. Sampling was performed on September 24, 2014, 18 days after stream flows were impacted by any runoff, and 59 days after a rain event greater than 0.5 inches.

Sampling Procedures

Kleinfelder field staff collected periphyton samples at each location in accordance with *Pennsylvania DEP Field Protocol: Periphyton Standing Crop and Species Assemblages* (December 2013). One to three substrate (rock) samples were collected at random locations along three transects at each location (a total of three to nine rocks at each location). Periphyton material was scraped by Kleinfelder staff in the field; all algal material was removed from a fixed area of each rock using a Pennsylvania Epilithic Periphyton (PEP) Sampler with brush-tipped Dremel tool (see photo on right). Algal slurries were stored in 1-liter amber glass containers with ice in a cooler and transported to QC Laboratories (PA 09-00131) on the same day.

Kleinfelder field staff also collected a single water quality sample at each location such that it was representative of the stream cross section. At least three subsurface grab samples were collected across the stream in order to obtain a representative sample. These grab samples were then composited in a larger volume container, from which the desired volume was transferred to a sample bottle. A dedicated large volume container was assigned to each sample location. Prior to each sampling event, the large volume containers were decontaminated according to the following procedure: (1) distilled/deionized water rinse; (2) non-phosphate detergent wash; (3) distilled/deionized water rinse; (4) air dry; and (5) distilled/deionized water rinse. Samples were preserved with sulfuric acid and stored in 500-ml plastic containers with ice in a cooler and transported to QC Laboratories (PA 09-00131) on the same day.

Sample Analyses

QC Laboratories (PA 09-00131), a PA-certified laboratory, provided new sample containers and performed all sample analyses. The total volume of algal slurry was measured in the laboratory, and a slurry subsample was analyzed for chlorophyll-a using EPA Method 446. Chlorophyll-a density was calculated based on the area scraped and the volume of algal slurry produced. The stream sample was analyzed for total phosphorus using Standard Method 4500P.

Quality Assurance and Quality Control

Chain of custody procedures were followed for all samples collected for this study. A sample is in someone's "custody" if:

- It is in one's actual physical possession;
- It is in one's view, after being in one's physical possession;
- It is in one's physical possession and then locked up so that no one can tamper with it; and
- It is kept in a secured area, restricted to authorized personnel only.

Calibration and preventive maintenance of laboratory equipment were in accordance with 40 CFR Part 136.

Preservation techniques, holding times, and measurements of the sampled parameters were performed in accordance with 40 CFR Part 136. A temperature blank was used to verify preservation requirements. No deviations from the test procedures and/or preservation methods and holding times occurred.

40 CFR Part 136 was followed for all quality assurance and quality control (QA/QC) practices, including detection limits, quantitation limits, precision, and accuracy.

Project Organization and Responsibility

Overall Project Coordination Officer: James F. Cosgrove, Jr., P.E.
Overall QA Officer: Joseph Schwarz
Performance/Systems Auditing: Thomas Amidon
Data Processing/Data Quality Review Officer: Thomas Amidon
Sampling Operations Field Supervisor: Joseph Schwarz
Laboratory QA Officer: Robert Martino, QCL
Laboratory Director: Ommen V. Kappil, QCL

IV. RESULTS

The laboratory data report is provided in Appendix B. Benthic periphyton density at each location was calculated based on the measurements in Table 2 below. The PEP sampler was used to scrape a circle with an area of 20.3 cm^2 from each rock. Slurry volume and Chlorophyll-a concentration were measured in the laboratory. Photo-Documentation of individual periphyton substrate samples is provided in Appendix C.

Table 2: Benthic Periphyton Measurements

Site ID	# Rocks	Area Scraped (cm^2)	Total Slurry Volume (mL)	Chlorophyll-a (mg/L)
IC-1U	8	162.4	497	10.9
IC-2S	9	182.7	505	11.1
IC-3U	3	60.9	233	21.6
PP-IU	3	60.9	280	15.0
IC-4S	9	182.7	641	8.9
IC-5S	9	182.7	530	17.1

Benthic periphyton density was calculated based on the slurry volume and concentration, as well as the area of substrate scraped:

$$PeriphytonDensity\ (mg/m^2) = \frac{SlurryVolume\ (ml) * SlurryConcentration\ \left(\frac{mg}{L}\right)}{AreaScraped\ (cm^2)} * 10$$

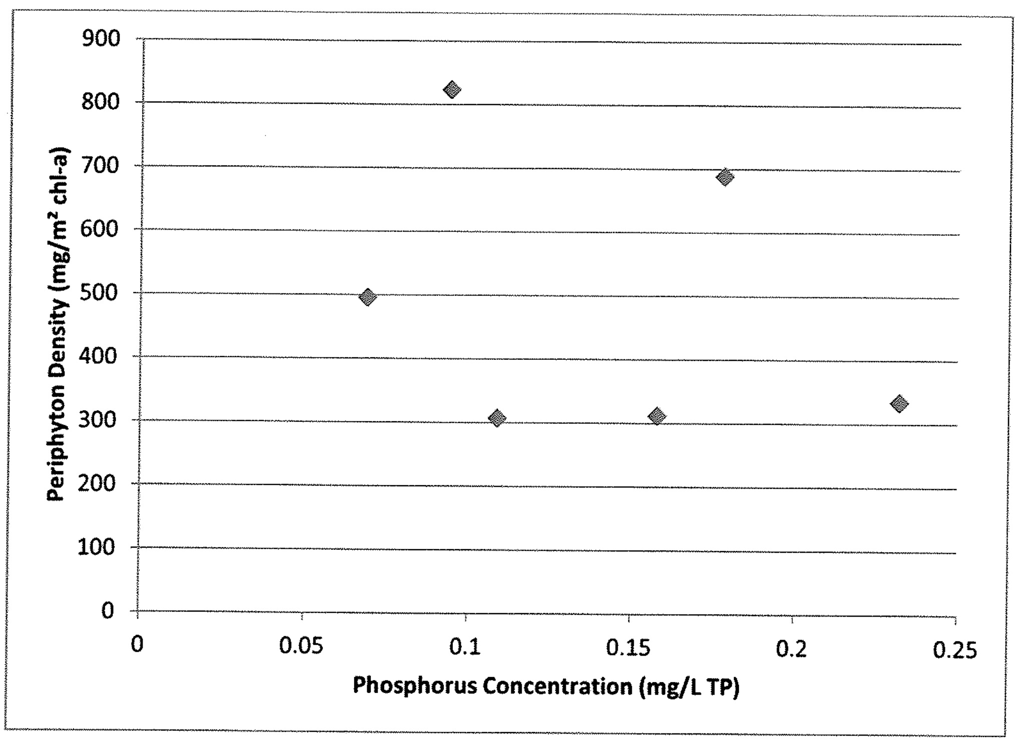
Periphyton density and total phosphorus concentration at each location are provided in Table 3 below, along with the estimated degree of shade at each site. Periphyton densities were significant at all locations, reflecting the optimal conditions during which sampling occurred.

Table 3: Periphyton and Phosphorus Results

Site ID	Periphyton Chlorophyll-a (mg/m²)	Total Phosphorus (mg/L)	Percent Unshaded
IC-1U	335	0.232	70%
IC-2S	308	0.109	0%
IC-3U	824	0.094	100%
PP-IU	689	0.178	100%
IC-4S	312	0.158	0%
IC-5S	496	0.069	0%

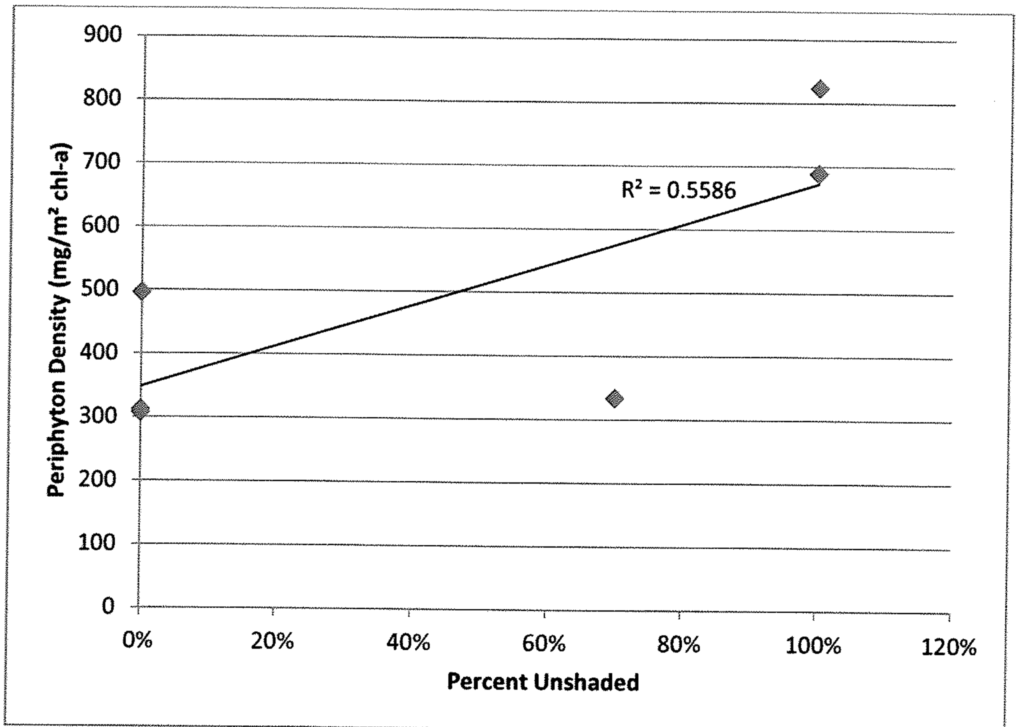
As shown in Figure 2, periphyton density in the Indian Creek watershed was not at all correlated with phosphorus concentration.

Figure 2: Periphyton Density versus Phosphorus Concentration



As shown in Figure 3, periphyton density was somewhat related to the degree of shading, which explained about half of the variance in periphyton density among the sites. However, even at completely shaded locations (i.e., 0% Unshaded), periphyton densities ranged from 300 to 500 mg/m² chlorophyll-a.

Figure 3: Periphyton Density versus Percent Unshaded



V. CONCLUSIONS

On behalf of the Telford Borough Authority and at the direction of its Attorney, John C. Hall, Kleinfelder performed a periphyton density and phosphorus concentration survey at six locations throughout the Indian Creek watershed. The survey was conducted in accordance with relevant PADEP protocols and a professional standard of care; laboratory analyses were conducted by a PADEP-certified laboratory. The survey was performed on a single day (September 24, 2014) when conditions were appropriate for assessing nutrient impacts. No relationship between phosphorus concentration and periphyton density was detected in the Indian Creek watershed. It does appear that the degree of shading accounts for at least some of the differences in periphyton density that were detected among the locations in the Indian Creek watershed. Results can be relied upon for environmental and regulatory assessment purposes.

APPENDIX A

Sampling Site Photos

IC-1u

IC-2s

IC-3u

IC-4s

IC-5s

PP-1u

APPENDIX B

Laboratory Results

QC LABORATORIES

Analytical Report

Serialized: 11/03/2014 09:32am QC21

JOSEPH SCHWARZ
KLEINFELDER EAST, INC.
RESEARCH PARK
321 WALL STREET
PRINCETON,NJ 08540

Regarding:

KLEINFELDER EAST, INC.
RESEARCH PARK
321 WALL STREET
PRINCETON, NJ 08540

PROJECT ID:

C00224

LABORATORY REPORT NUMBER:

L5257442

PO NUMBER:

6496

REVISED REPORT NOTIFICATION

The Chlorophyll A results were revised.

NELAP ACCREDITED TNI LABORATORY

Oommen V. Kappil

Authorized by: Oommen V. Kappil, QA Director

QCL Accreditations: Southampton Div: EPA ID PA00018; NELAP ID's: PA 09-00131, NJ PA166, NY 11223
State ID's: CT PH-0768, DE PA-018, MD 206, SC 89021001; FDA Reg. #: 2515238
Delaware Division: State ID's: DE 00011, MD 138
Vineland Division: State ID: NJ 06005; Reading Div: State ID: PA 06-03543
Wind Gap Division: State ID's: PA 48-01334, NJ PA001
E. Rutherford Division: State ID: NJ 02015

QC Laboratories

Analytical Report

KLEINFELDER EAST, INC.
C00224

P.O. No: 6496
Inv. No: 1652286 PI
PWSID:

JOSEPH SCHWARZ
KLEINFELDER EAST, INC.
RESEARCH PARK
321 WALL STREET
PRINCETON, NJ 08540

Regarding:
JOSEPH SCHWARZ
KLEINFELDER EAST, INC.
RESEARCH PARK
321 WALL STREET
PRINCETON, NJ 08540

SAMPLE SUMMARY

Lab ID	Collected	Received	Matrix	Client ID
L5257442-1	09/24/14 09:30	09/26/14 10:04	WASTEWATER	INDIAN POINT, IC-1U
L5257442-2	09/24/14 10:40	09/26/14 10:04	WASTEWATER	IC-2S
L5257442-3	09/24/14 11:30	09/26/14 10:04	WASTEWATER	IC-3U
L5257442-4	09/24/14 13:45	09/26/14 10:04	WASTEWATER	PP-IU
L5257442-5	09/24/14 13:00	09/26/14 10:04	WASTEWATER	IC-4S
L5257442-6	09/24/14 14:15	09/26/14 10:04	WASTEWATER	IC-5S

PIN: 56623

This report is a revision of report number 4171286
Serial Number: 4171326

QC Laboratories

Analytical Report

Sample Description:	INDIAN POINT, IC-1U		
Sample Number:	L5257442-1	Samp. Date/Time/Temp:	09/24/14 09:30am NA C
Matrix:	WASTEWATER	Sampled by:	Customer
Received Temp:	2.3 C	Iced (Y/N):	Y

GENERAL CHEMISTRY

Analytical Method:	SM 4500P B.5 E	Run Date:	10/02/14 09:40AM	Workgroup:	100214TP1
Dilution:	3	Analyst:	NM	File ID:	p_tot_1003_0808.csv
Units:	mg/l	Instrument:	Genysis 20	Basis:	

Parameter	CAS	Result	MDL*	RL
Phosphorus, total as P	N/A	0.232	0.0210	0.0300

AQUATIC TOXICOLOGY DIVISION

Analytical Method:	EPA 446.0	Run Date:	09/30/14 10:40AM	Workgroup:	
Dilution:		Analyst:	MV	File ID:	
Units:		Instrument:		Basis:	

Parameter	CAS	Result	MDL*	RL
Chlorophyll a	N/A	334.58	0.1000	

Sample Comments:
QC Laboratories does not hold NELAC certification for chlorophyll A.

The Chloropyll A results are in mg/m2.

*=This limit was used in the evaluation of the final result.

This report is a revision of report number 4171286

PIN: 56623

Serial Number: 4171326

Sample Description:	IC-2S		
Sample Number:	L5257442-2	Samp. Date/Time/Temp:	09/24/14 10:40am NA C
Matrix:	WASTEWATER	Sampled by:	Customer
Received Temp:	2.3 C	Iced (Y/N):	Y

GENERAL CHEMISTRY

Analytical Method:	SM 4500P B.5 E	Run Date:	10/02/14 09:40AM	Workgroup:	100214TP1
Dilution:	3	Analyst:	NM	File ID:	p_tot_1003_0808.csv
Units:	mg/l	Instrument:	Genysis 20	Basis:	

Parameter	CAS	Result	MDL*	RL
Phosphorus, total as P	N/A	0.109	0.0210	0.0300

AQUATIC TOXICOLOGY DIVISION

Analytical Method:	EPA 446.0	Run Date:	09/30/14 10:40AM	Workgroup:	
Dilution:		Analyst:	MV	File ID:	
Units:		Instrument:		Basis:	

Parameter	CAS	Result	MDL*	RL
Chlorophyll a	N/A	308.097	0.1000	

Sample Comments:
QC Laboratories does not hold NELAC certification for chlorophyll A.

The Chloropyll A results are in mg/m2.

*=This limit was used in the evaluation of the final result.

This report is a revision of report number 4171286

PIN: 56623

Serial Number: 4171326

QC Laboratories

Analytical Report

Sample Description:	IC-3U		
Sample Number:	L5257442-3	Samp. Date/Time/Temp:	09/24/14 11:30am NA C
Matrix:	WASTEWATER	Sampled by:	Customer
Received Temp:	2.3 C	Iced (Y/N):	Y

GENERAL CHEMISTRY

Analytical Method:	SM 4500P B.5 E	Run Date:	10/02/14 09:40AM	Workgroup:	100214TP1
Dilution:	3	Analyst:	NM	File ID:	p_tot_1003_0808.csv
Units:	mg/l	Instrument:	Genysis 20	Basis:	

Parameter	CAS	Result	MDL*	RL
Phosphorus, total as P	N/A	0.0940	0.0210	0.0300

AQUATIC TOXICOLOGY DIVISION

Analytical Method:	EPA 446.0	Run Date:	09/30/14 10:40AM	Workgroup:	
Dilution:		Analyst:	MV	File ID:	
Units:		Instrument:		Basis:	

Parameter	CAS	Result	MDL*	RL
Chlorophyll a	N/A	824.276	0.1000	

Sample Comments:
QC Laboratories does not hold NELAC certification for chlorophyll A.

The Chloropyll A results are in mg/m2.

*=This limit was used in the evaluation of the final result.

This report is a revision of report number 4171286

PIN: 56623

Serial Number: 4171326

QC Laboratories

Analytical Report

Sample Description:	PP-IU		
Sample Number:	L5257442-4	Samp. Date/Time/Temp:	09/24/14 01:45pm NA C
Matrix:	WASTEWATER	Sampled by:	Customer
Received Temp:	2.3 C	Iced (Y/N):	Y

GENERAL CHEMISTRY

Analytical Method:	SM 4500P B.5 E	Run Date:	10/02/14 09:40AM	Workgroup:	100214TP1
Dilution:	3	Analyst:	NM	File ID:	p_tot_1003_0808.csv
Units:	mg/l	Instrument:	Genysis 20	Basis:	

Parameter	CAS	Result	MDL*	RL
Phosphorus, total as P	N/A	0.178	0.0210	0.0300

AQUATIC TOXICOLOGY DIVISION

Analytical Method:	EPA 446.0	Run Date:	09/30/14 10:40AM	Workgroup:	
Dilution:		Analyst:	MV	File ID:	
Units:		Instrument:		Basis:	

Parameter	CAS	Result	MDL*	RL
Chlorophyll a	N/A	689.45	0.1000	

Sample Comments:
QC Laboratories does not hold NELAC certification for chlorophyll A.

The Chloropyll A results are in mg/m2.

*=This limit was used in the evaluation of the final result.

This report is a revision of report number 4171286

PIN: 56623

Serial Number: 4171326

QC Laboratories

Analytical Report

Sample Description:	IC-4S		
Sample Number:	L5257442-5	Samp. Date/Time/Temp:	09/24/14 01:00pm NA C
Matrix:	WASTEWATER	Sampled by:	Customer
Received Temp:	2.3 C	Iced (Y/N):	Y

GENERAL CHEMISTRY

Analytical Method:	SM 4500P B.5 E	Run Date:	10/02/14 09:40AM	Workgroup:	100214TP1
Dilution:	3	Analyst:	NM	File ID:	p_tot_1003_0808.csv
Units:	mg/l	Instrument:	Genysis 20	Basis:	

Parameter	CAS	Result	MDL*	RL
Phosphorus, total as P	N/A	0.158	0.0210	0.0300

AQUATIC TOXICOLOGY DIVISION

Analytical Method:	EPA 446.0	Run Date:	09/30/14 10:40AM	Workgroup:	
Dilution:		Analyst:	MV	File ID:	
Units:		Instrument:		Basis:	

Parameter	CAS	Result	MDL*	RL
Chlorophyll a	N/A	312.293	0.1000	

Sample Comments:
QC Laboratories does not hold NELAC certification for chlorophyll A.

The Chloropyll A results are in mg/m2.

*=This limit was used in the evaluation of the final result.

This report is a revision of report number 4171286

PIN: 56623

Serial Number: 4171326

QC Laboratories

Analytical Report

Sample Description:	IC-5S		
Sample Number:	L5257442-6	Samp. Date/Time/Temp:	09/24/14 02:15pm NA C
Matrix:	WASTEWATER	Sampled by:	Customer
Received Temp:	2.3 C	Iced (Y/N):	Y

GENERAL CHEMISTRY

Analytical Method:	SM 4500P B.5 E	Run Date:	10/02/14 09:40AM	Workgroup:	100214TP1
Dilution:	3	Analyst:	NM	File ID:	p_tot_1003_0808.csv
Units:	mg/l	Instrument:	Genysis 20	Basis:	

Parameter	CAS	Result	MDL*	RL
Phosphorus, total as P	N/A	0.0690	0.0210	0.0300

AQUATIC TOXICOLOGY DIVISION

Analytical Method:	EPA 446.0	Run Date:	09/30/14 10:40AM	Workgroup:	
Dilution:		Analyst:	MV	File ID:	
Units:		Instrument:		Basis:	

Parameter	CAS	Result	MDL*	RL
Chlorophyll a	N/A	496.268	0.1000	

Sample Comments:
QC Laboratories does not hold NELAC certification for chlorophyll A.

The Chloropyll A results are in mg/m2.

*=This limit was used in the evaluation of the final result.

This report is a revision of report number 4171286

PIN: 56623

Serial Number: 4171326

DEFINITIONS

The following terms or abbreviations are used in this report:

MPN	Most probable number
CFU	Colony forming unit
POS	Positive
NEG	Negative
PRES	Presumptive
MF	Membrane Filtration
TNTC	Too numerous to count
PL	Customer-specific limit
DF	Dilution Factor (For Microbiology, DF = volume of sample tested)
QUAL	Qualifier
NTU	Nephelometric turbidity units
RL	Laboratory reporting limit or Limit of Quantitation (LOQ)
MCL	EPA recommended "Maximum Contaminant Level"
MDL	Method Detection Limit

ND	The analyte was not detected at a concentration above the RL / MDL.
J	Estimated value ≥ MDL but < RL. Applies to organics and general chemistry results (see below for metals)
Q	Indicates this analyte did not meet quality control requirements.
DRY	Indicates the result was calculated and reported on a dry weight basis.
TIC	Tentatively Identified Compounds (Library Search Compounds); concentrations are estimated values only.
ppm (mg/l)	Parts per million: equivalent to 1 milligram per kilogram (mg/Kg) for solids or one milligram per liter (mg/L) for aqueous samples.
ppb (ug/L)	Parts per billion: equivalent to 1 microgram per kilogram (ug/Kg) for solids or one microgram per liter (ug/L) for aqueous samples.
<	Less than: In conjunction with a numerical value, indicates a concentration less than RL / MDL.
>	Greater than: In conjunction with a numerical value, indicates a concentration greater than RL / MDL.

Data Qualifiers (EPA CLP Convention)

Organics		***Metals***	
B	Analyte was detected in the method blank	B	Value is ≥ MDL and < RL
E	Concentration exceeds calibration range	E	Estimated value due to presence of interference
U	Compound not detected above MDL/RL	M	Duplicate precision for an element outside control limit
N	Presumptive evidence of compound in library search	N	Spike recovery for an element outside control limits
P1	Column precision criteria not met, report lower value	U	Element not detected above MDL/RL
P2	Column precision criteria not met, report higher value	Other	Defined in case narrative or data package
Other	Defined in case narrative or data package		

Warranties, Terms, and Conditions

- Unless otherwise specified in the Parameter field, analyses (excluding "Field Parameters") were performed at the QCL Southampton Division (1205 Industrial Boulevard, Southampton, PA 18966). Food, pharmaceutical, and dairy testing were performed the QCL facility in Horsham (702 Electronic Drive, Horsham, PA 19044).
- The test results meet all TNI or other applicable regulatory agency requirements, including holding times and preservation, unless otherwise indicated.
- The report shall not be reproduced, except in full, without the written consent of the laboratory.
- All samples are collected as "grab" samples unless otherwise identified.
- The reported results relate only to the sample as tested. QCL is not responsible for sample integrity unless sampling has been performed by a member of our staff.
- QCL is not responsible for sampling and/or testing omissions. Note that regulatory authorities may assess substantial fines for testing omissions. Please track your sample collection schedules and results on a regular basis (e.g. weekly, monthly, or quarterly) to ensure compliance. QCL's internet program "LIVE ACCESS" will provide you with real-time access to collection dates and testing results. Please contact Customer Service for further information.
- The following personnel or their deputies have approved the results of the tests performed by QCL: Nicki Smith (Environmental Chemistry), Amanda Lukaszewski (Pharmaceutical), Ryan Baker (Dairy), Karen Battista (Food Micro), Jonathan Decenzi (Food Chemistry), Sue Abbott (QCL Delaware).

QCL Accreditations

Southampton Division	EPA ID:	PA00018
	NELAP IDs:	PA 09-00131; NJ PA166; NY 11223
	State IDs:	CT PH-0768; DE PA-018; MD 206
	FDA Reg #:	2515238
Delaware Division	State IDs:	DE 00011; MD 138
Wind Gap Division	State IDs:	PA 48-01334; NJ PA001
East Rutherford Division	State ID:	NJ 02015
Reading Division	State ID:	PA 06-03543
Vineland Division	State ID:	NJ 06005

C00224

QC Laboratories

1205 Industrial Blvd.
Southampton, PA 18966-0514
Phone: 215-355-3900
Fax: 215-355-7231

CHAIN OF CUSTODY

Page 1 of 1

Lab LIMS No: L525744-2

Client/Acct. No. Kleinfelder-~~East~~

Address 321 Wall street

City/State/Zip Princeton, NJ 08540

Phone/Fax 609 924 8821

Client Contact Joseph Schwarz

Bill to/Report to: (if different)

Sampling Site Address: (if different)

P.O. No. 6496

QC Contact Rob Hulit

LAB USE ONLY:

- # ___ Ascorbic/HCl Vials # ___ HCl Vials
- # ___ $Na_2S_2O_3$
- # ___ Na OH/Zn acetate pH
- # ___ HNO_3 pH
- # 6 H_2SO_4 pH < 2 250ml
- # ___ NaOH pH
- # ___ Unpreserved
- # ___ Hcl pH 2.3°C ICED
- # ___ Temp control ___ ID# 1243041B

MATRIX CODES

DW: DRINKING WATER
GW: GROUND WATER
WW: WASTEWATER
SO: SOIL
SL: SLUDGE
OIL: OIL
SOL: NON SOIL SOLID
MI: MISCELLANEOUS
X: OTHER

PROJECT

FIELD ID	Collection Date	Collection Military Time	GRAB	COMP	Matrix Code	Number of Containers Total	H_2SO_4	HCl	VOA	HNO_3	NaOH	ZnAc	Unpres	BOT	ANALYSIS REQUESTED	Field pH, Temp (C or F), DO, Cl_2, S. Cond. etc.
IC-1U	9/24/14	0930	✓		WW	2	1						1		Chl-a, TP, Chl-a (volume)	area = 162.4 cm^2
IC-2S	↓	1040	✓		WW	2	1						1		Chl-a, TP, Chl-a (volume)	area = 182.7 cm^2
IC-3U	↓	1130	✓		WW	2	1						1		Chl-a, TP, Chl-a (volume)	area = 60.9 cm^2
PP-1U	↓	1345	✓		WW	2	1						1		Chl-a, TP, Chl-a (volume)	area = 60.9 cm^2
IC-4S	↓	1300	✓		WW	2	1						1		Chl-a, TP, Chl-a (volume)	area = 182.7 cm^2
IC-5S	↓	1415	✓		WW	2	1						1		Chl-a, TP, Chl-a (volume)	area = 182.7 cm^2

SAMPLED BY: (Name/Company) JTS / Kleinfelder

Verbal/fax data due: ___/___/___
Hardcopy due: ___/___/___

Report Format: ☒ Standard ☐ Forms ☐ Standard + QC ☐ NJ Reduced ☐ Disk

Please call for pricing and availability on rush (<14-21 day) turnaround and on all but standard format.

Field Parameters Analyzed By:
Sig: [signature]
Date/Time: 9/24/14

SAMPLE CUSTODY EXCHANGES MUST BE DOCUMENTED BELOW. USE FULL LEGAL SIGNATURE, DATE AND MILITARY TIME (24 HOUR CLOCK. I.E. 8AM IS 0800, 4 PM IS 1600)

	RELINQUISHED BY	DATE	TIME	RECEIVED BY	DATE	TIME
1	[signature] (SAMPLER)	9/26/14	8:45	[signature]	9/26/14	0845
2	[signature]	9/26/14	10:04	[signature]	9/26/14	1004
3						
4						
5						

DELIVERY METHOD: ☒ QC COURIER ☐ CLIENT ☐ UPS ☐ FEDEX ☐ OTHER ___

Custody Seal Number

COMMENTS:

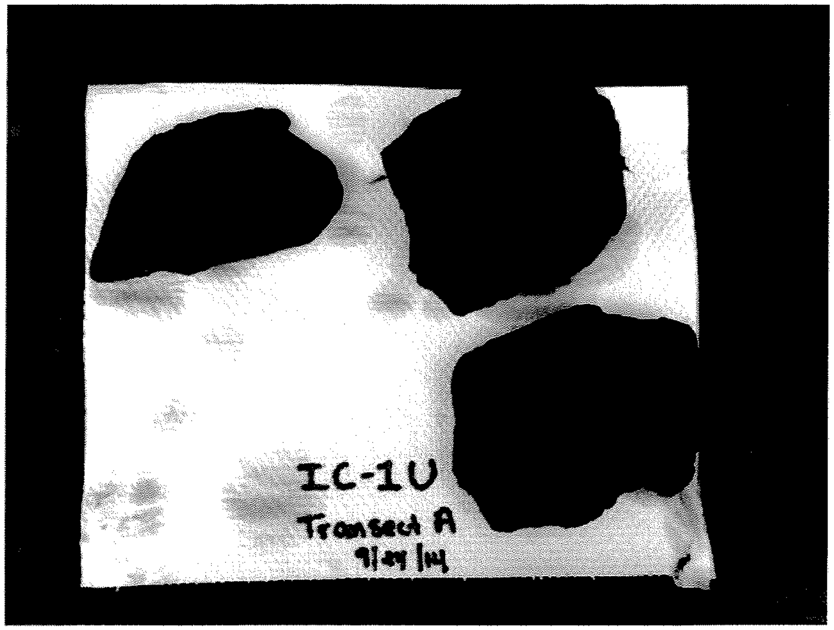
Hazardous: yes / no

For example to aid completion, see reverse side.

FINAL REPORT

APPENDIX C

Periphyton Substrate Photo-Documentation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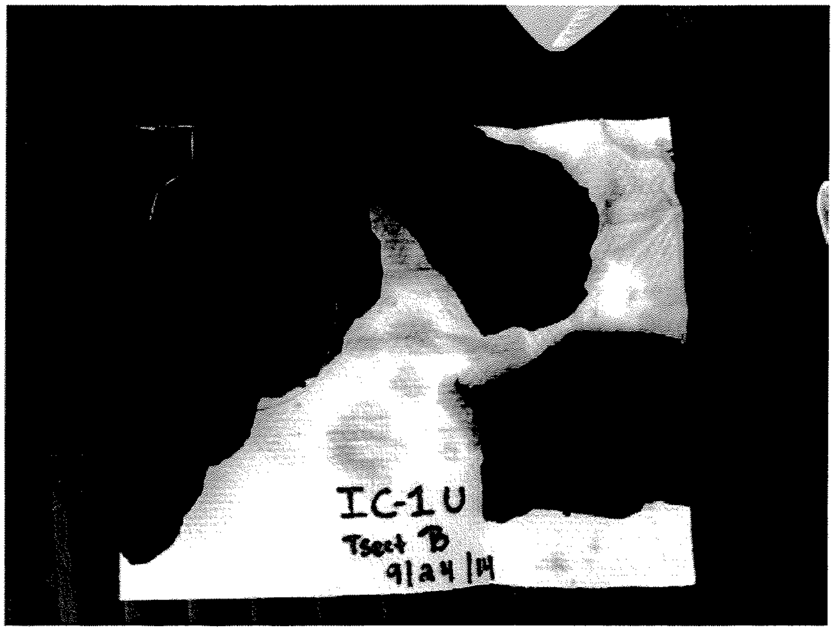
Transect A
9/29/14


IC-1U
Transect A
9/29/14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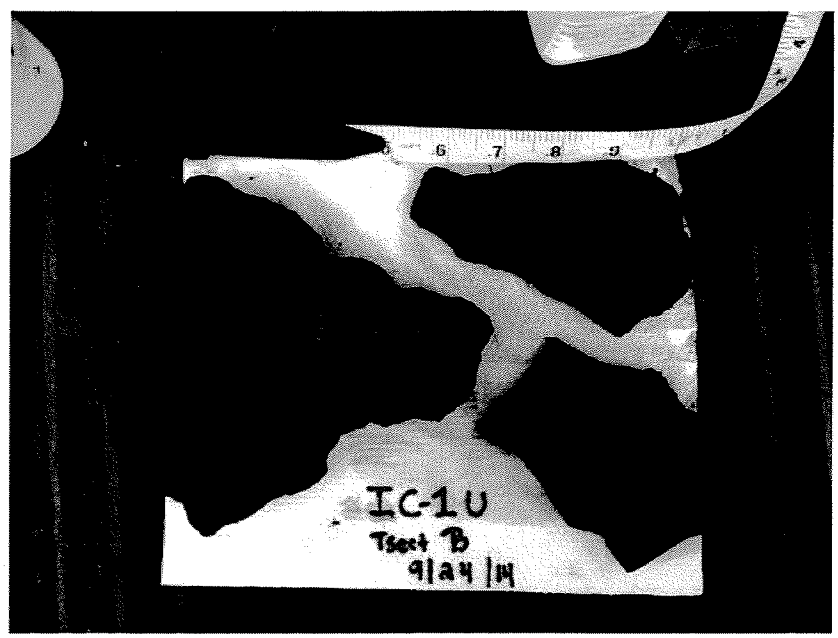
Tsect B
9/24/14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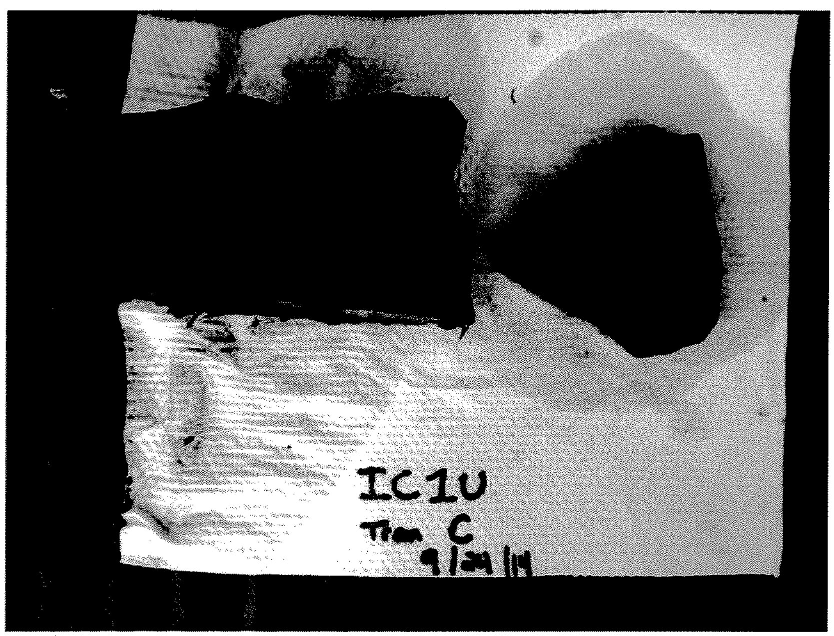
Tsect B
9/24/14


IC1U
Tran C
9/29/14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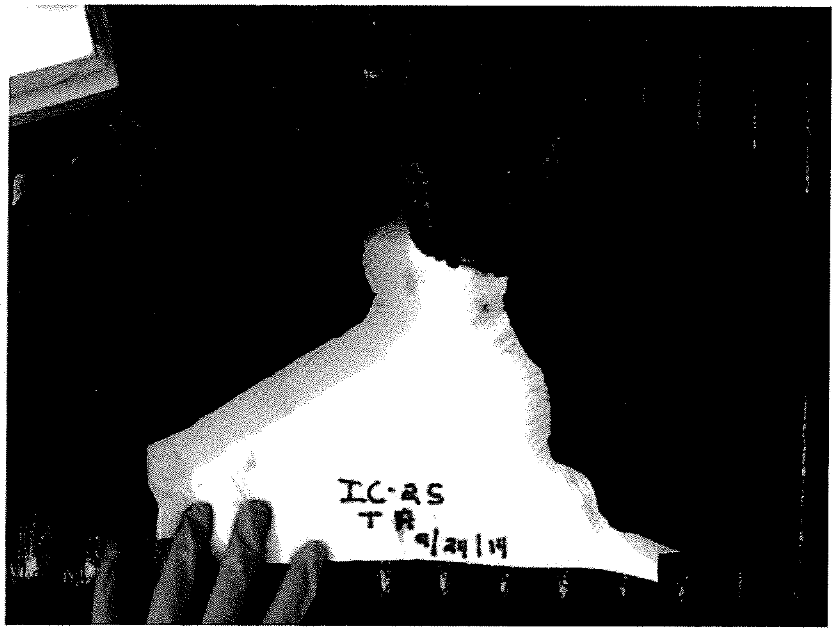
Tran C
9/29/14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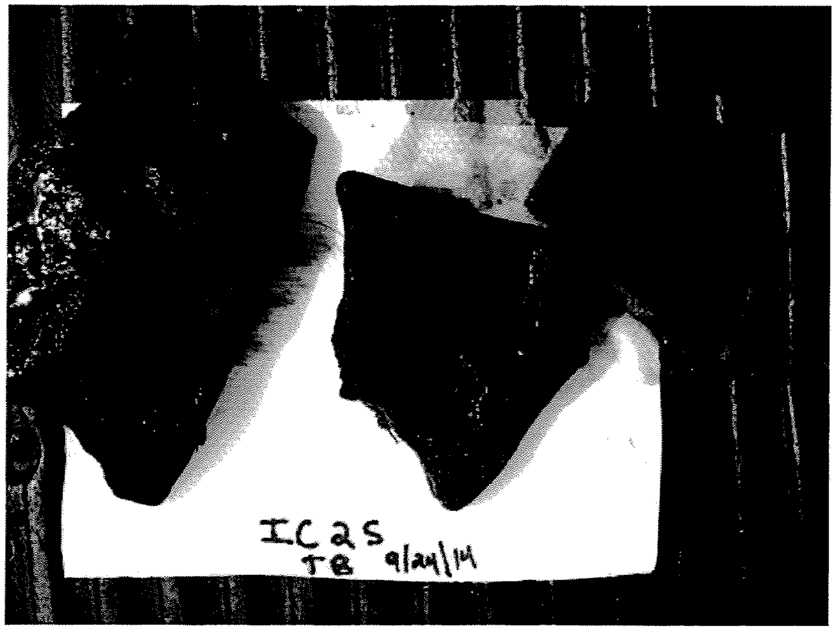
TR 9/24/14


IC-2S
TR 9/24/14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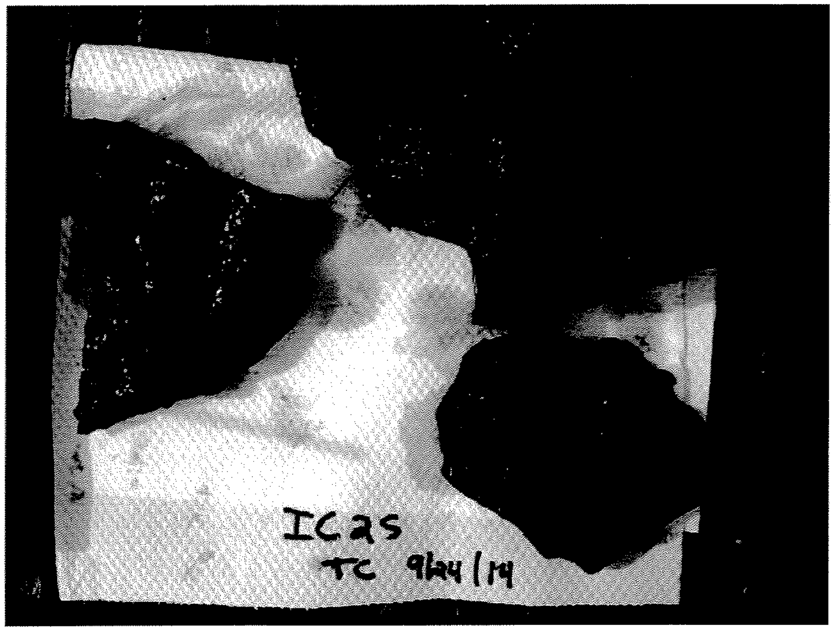
TB 9/24/14


IC2S
TB 9/24/14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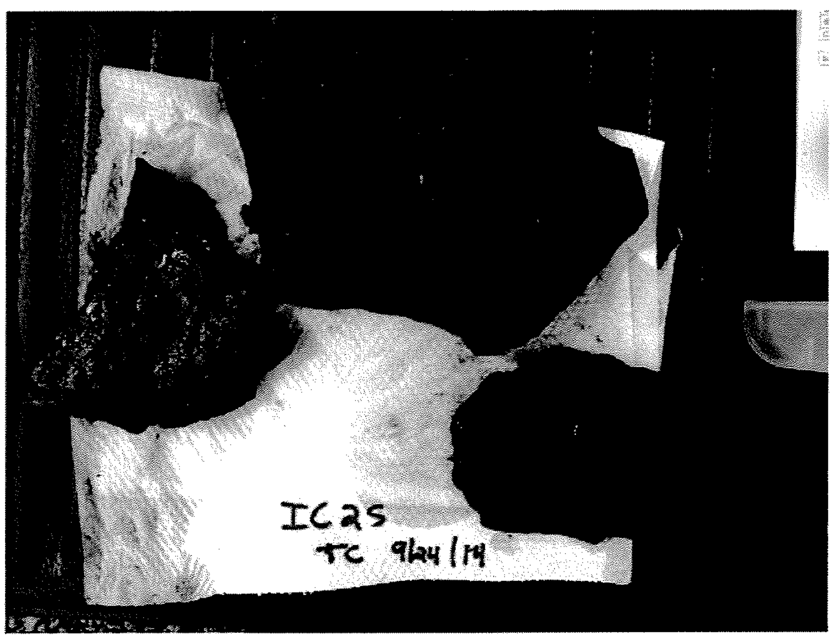
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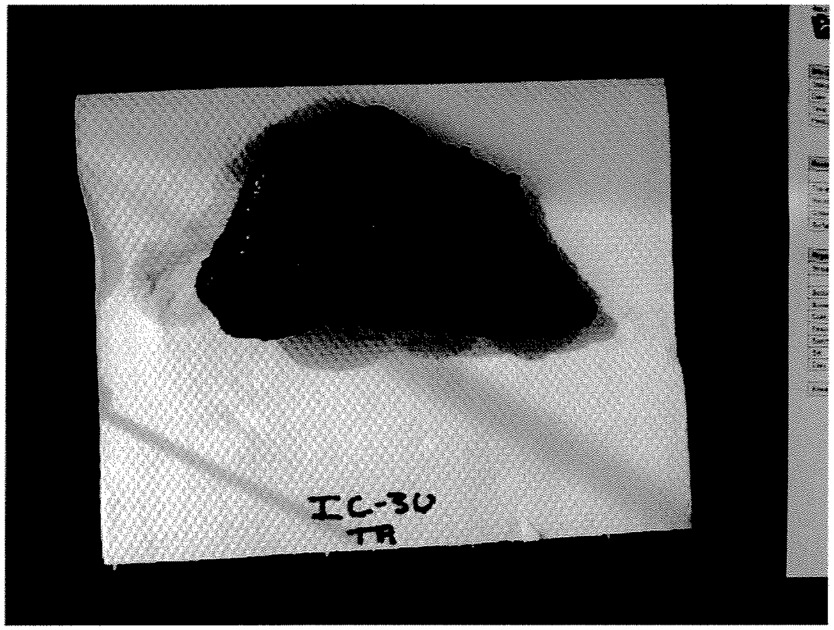
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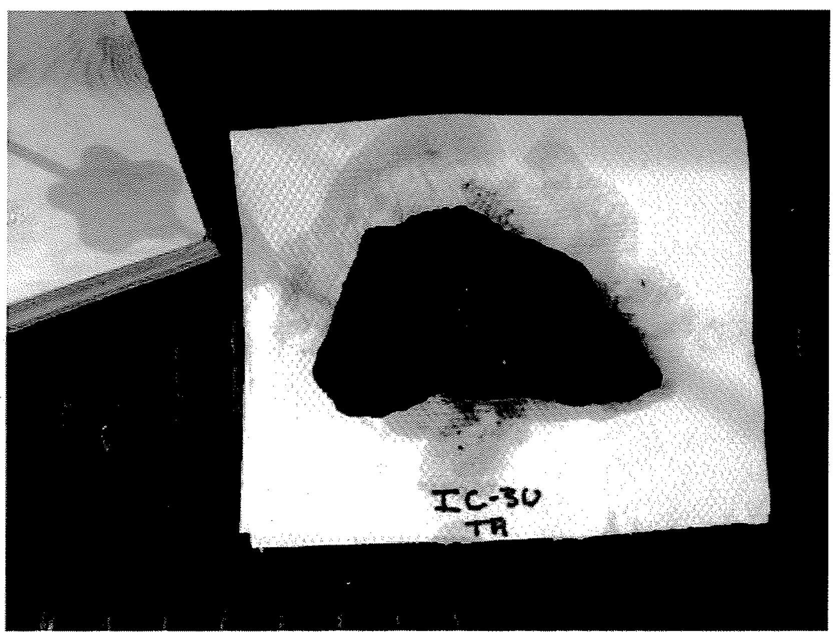
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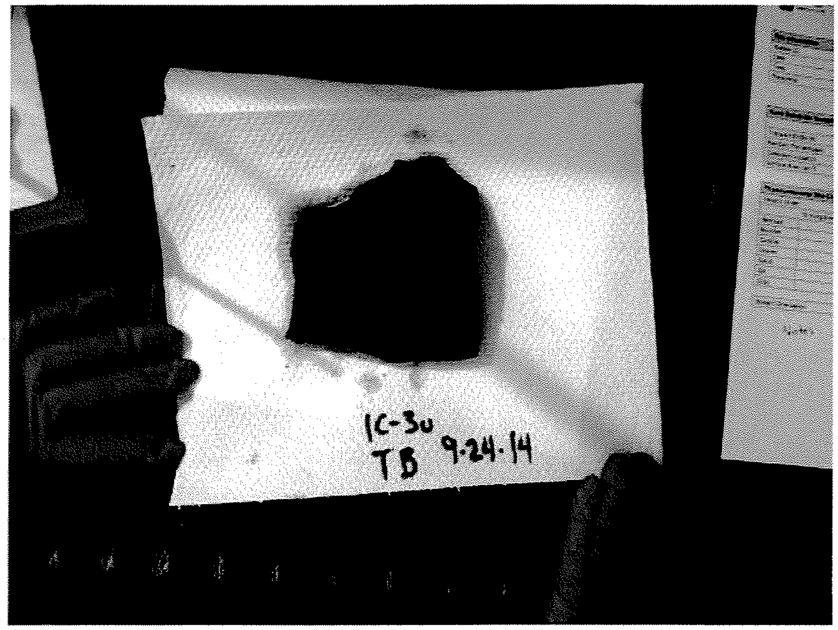
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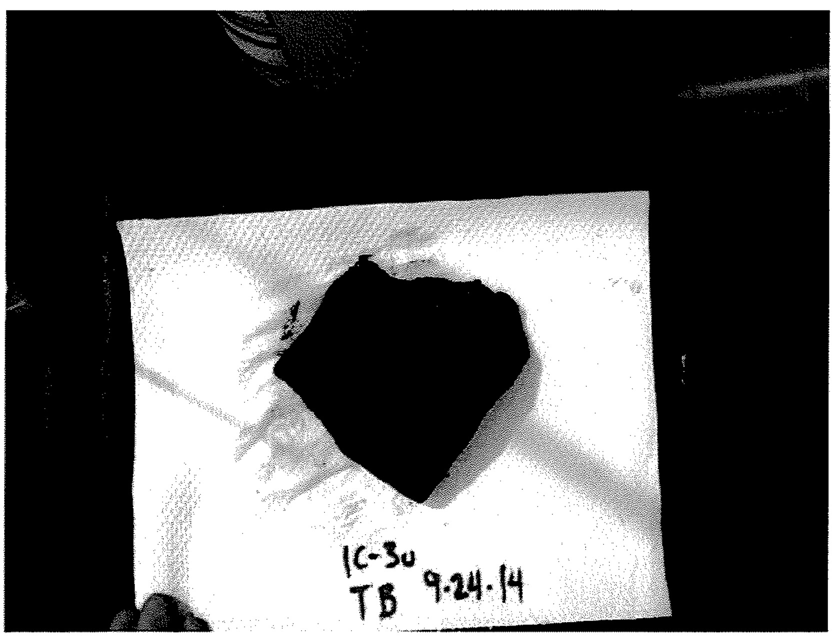
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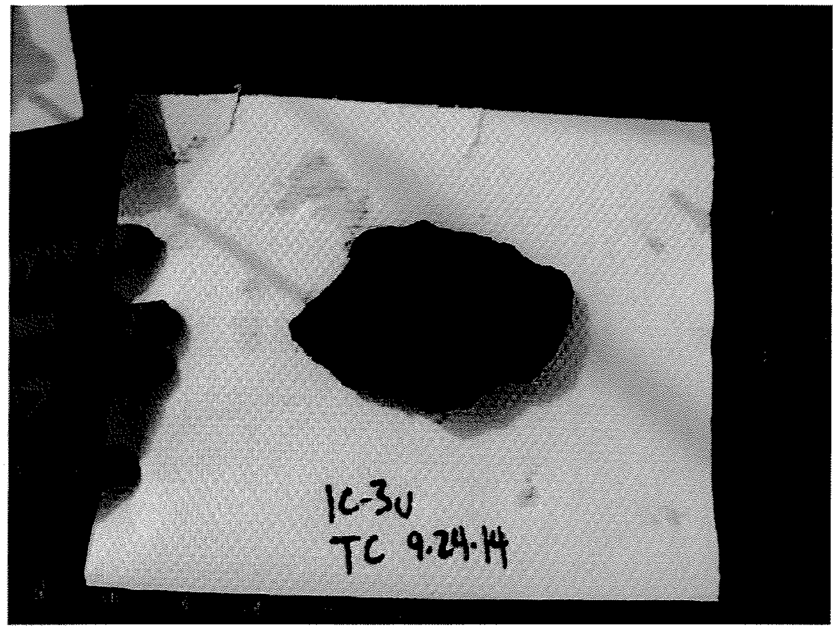
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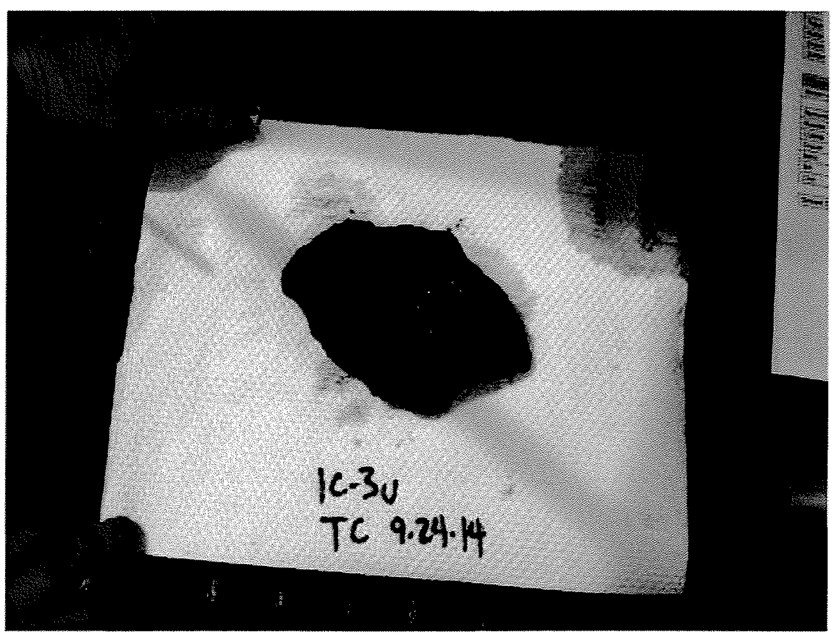
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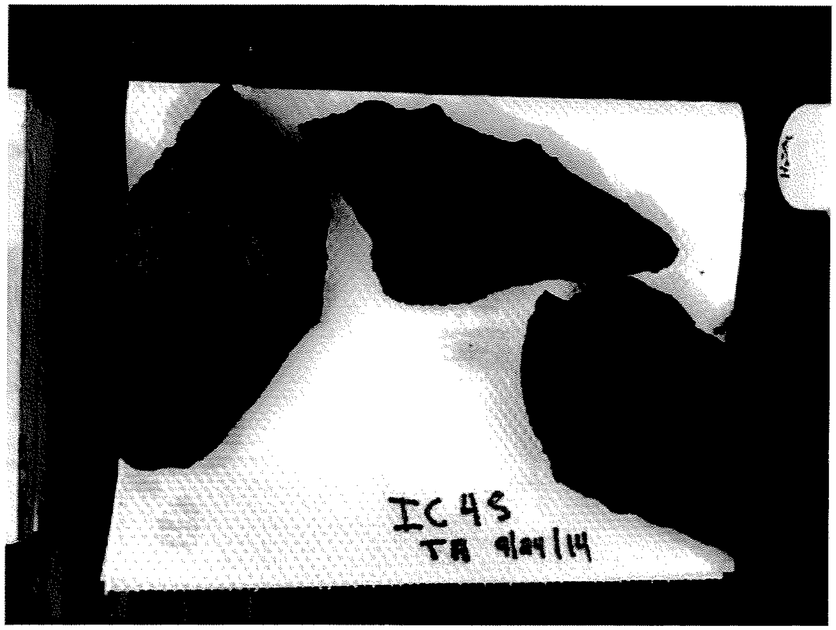
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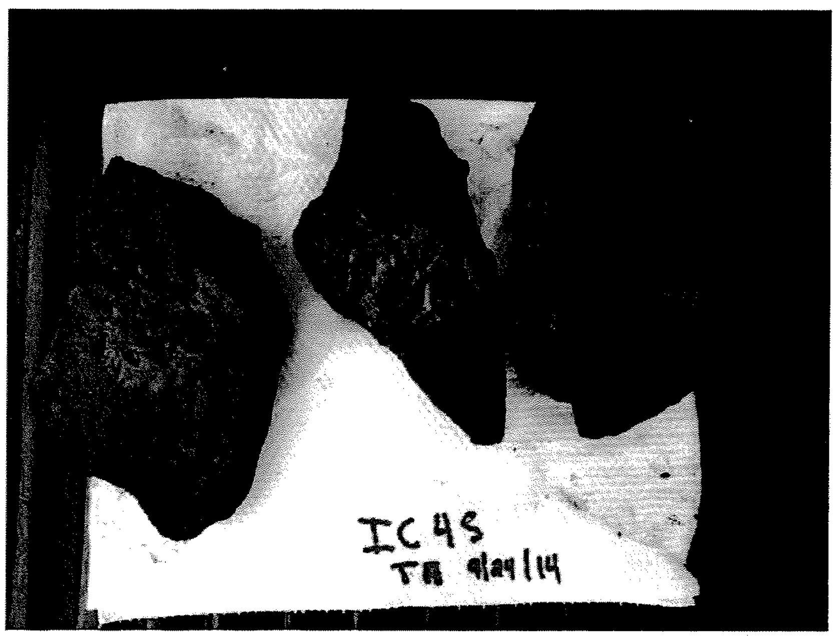
TA 9/24/14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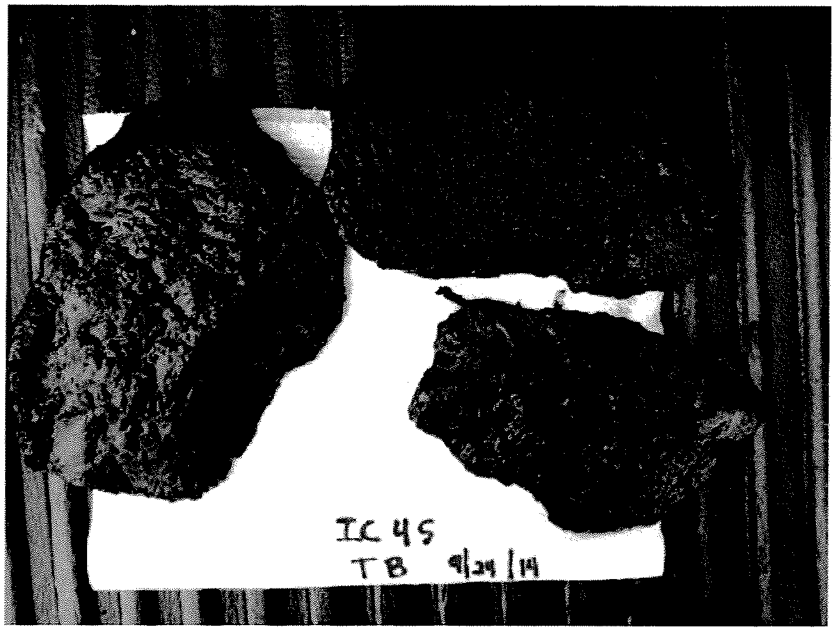
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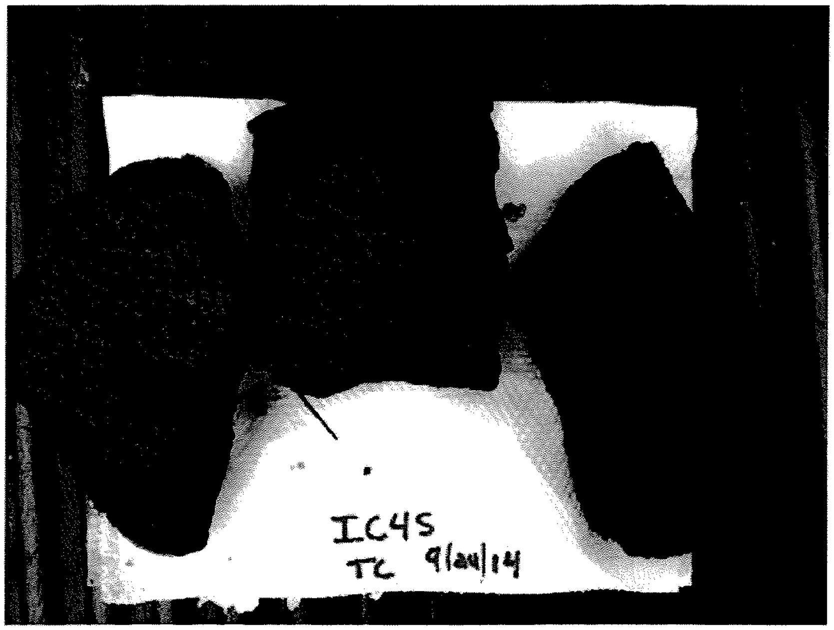
TB 9/24/14


IC 45
TB 9/24/14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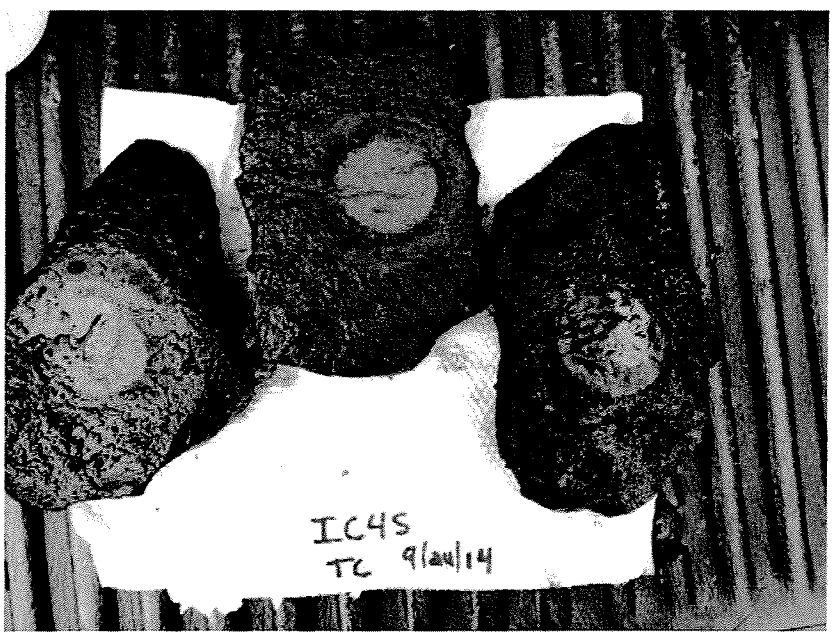
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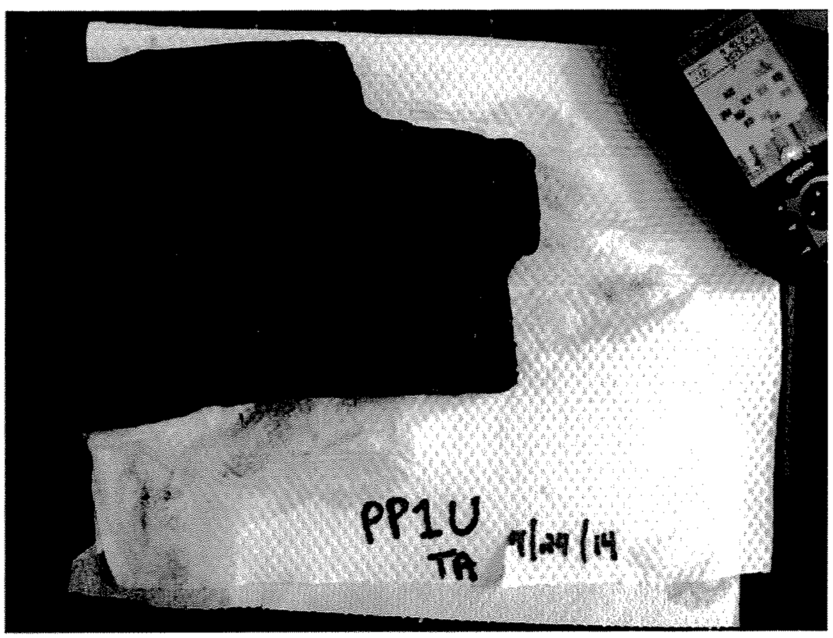
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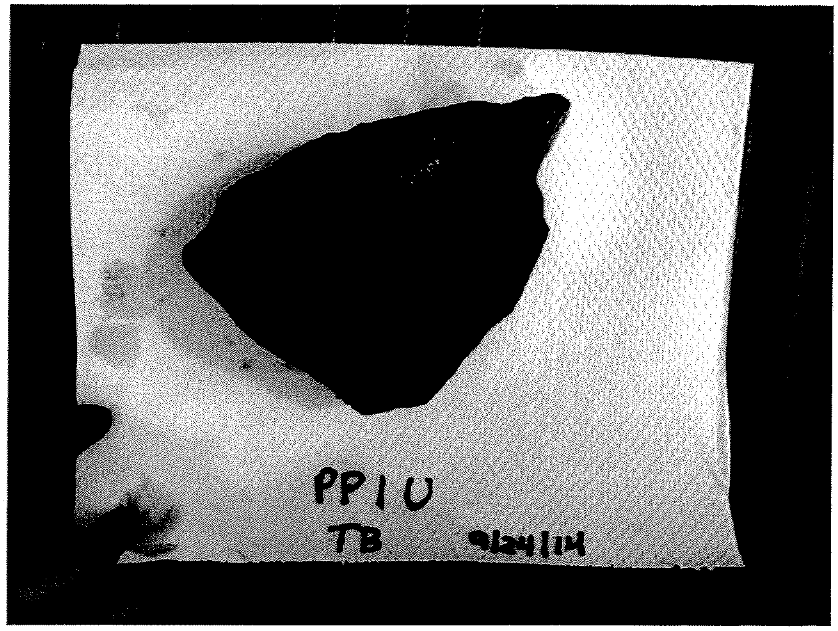
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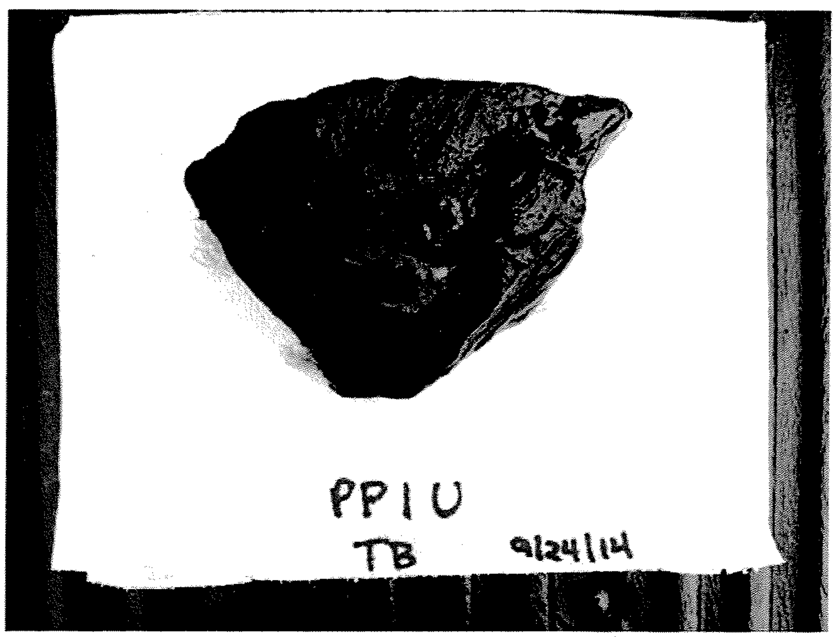
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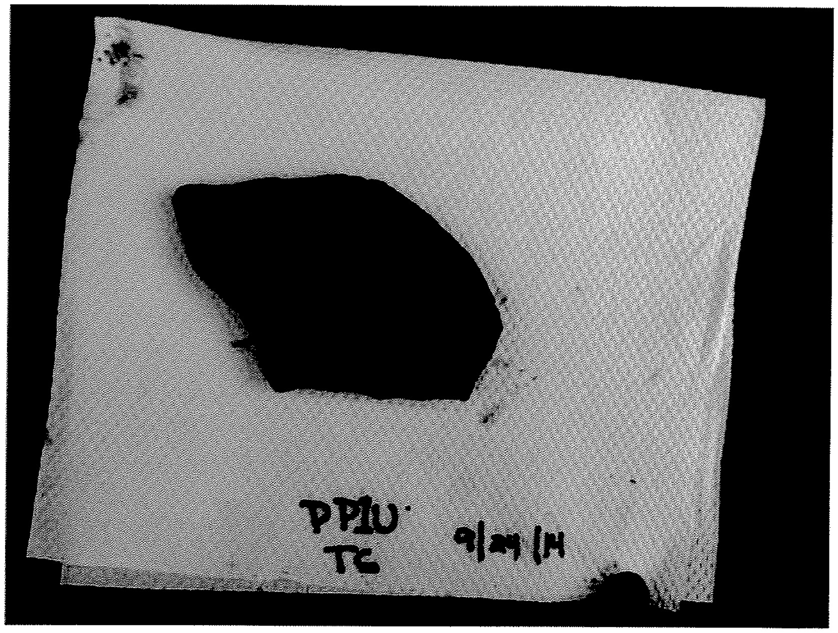
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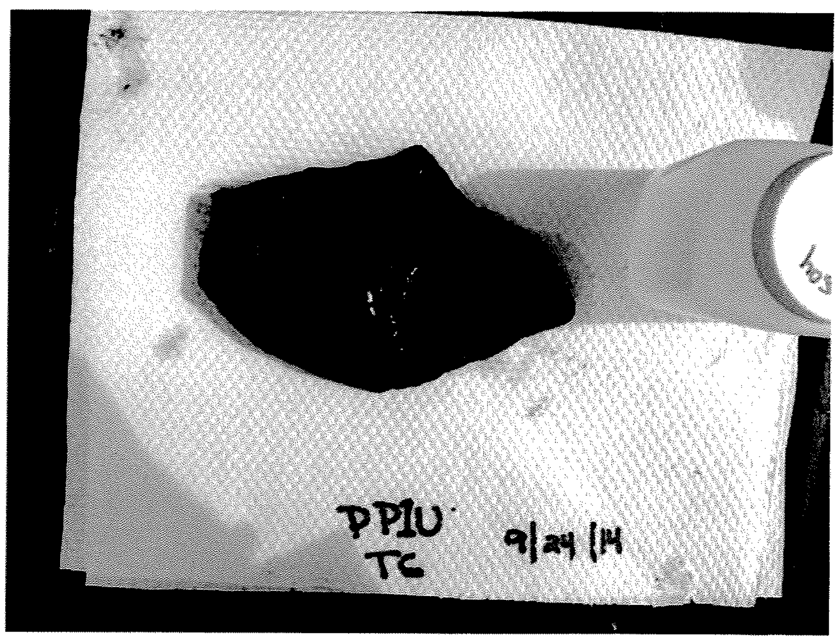
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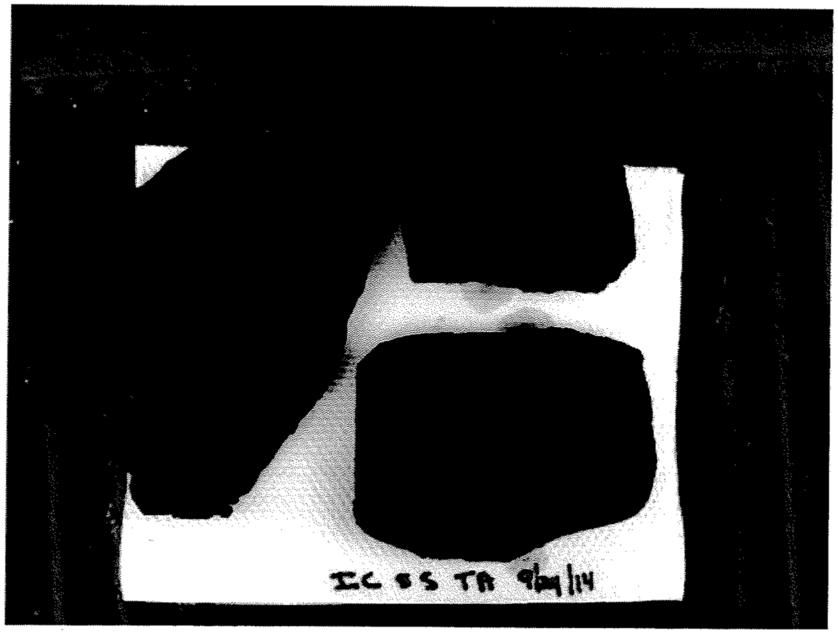
9/24/14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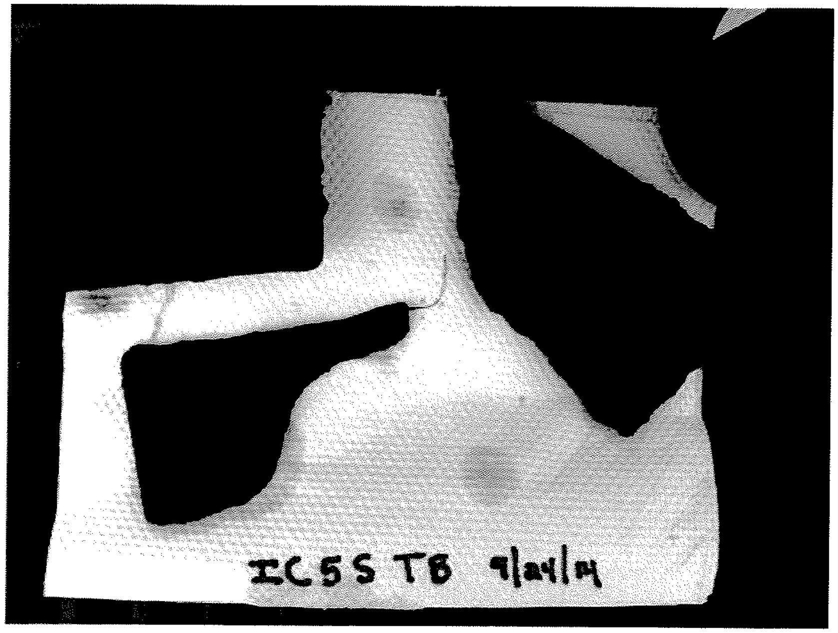
IC SS TA 9/24/14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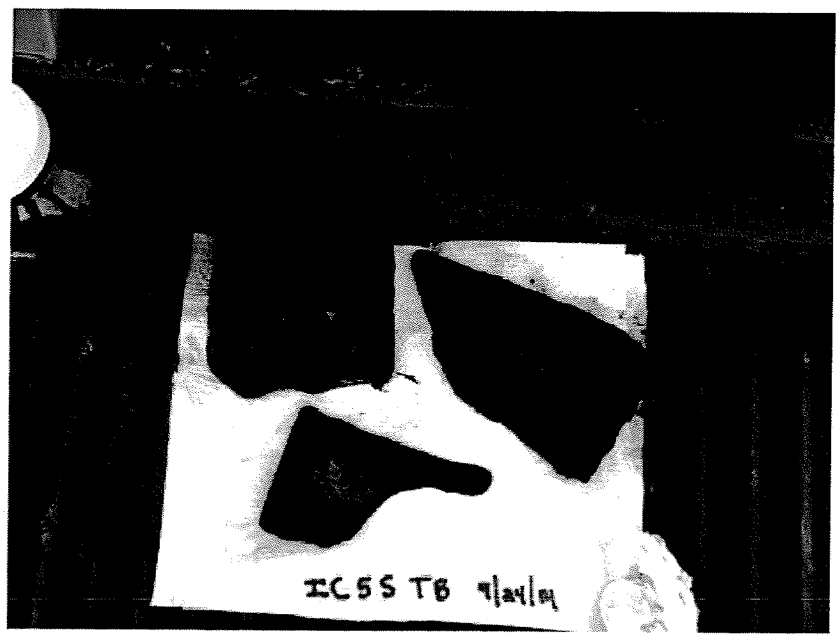
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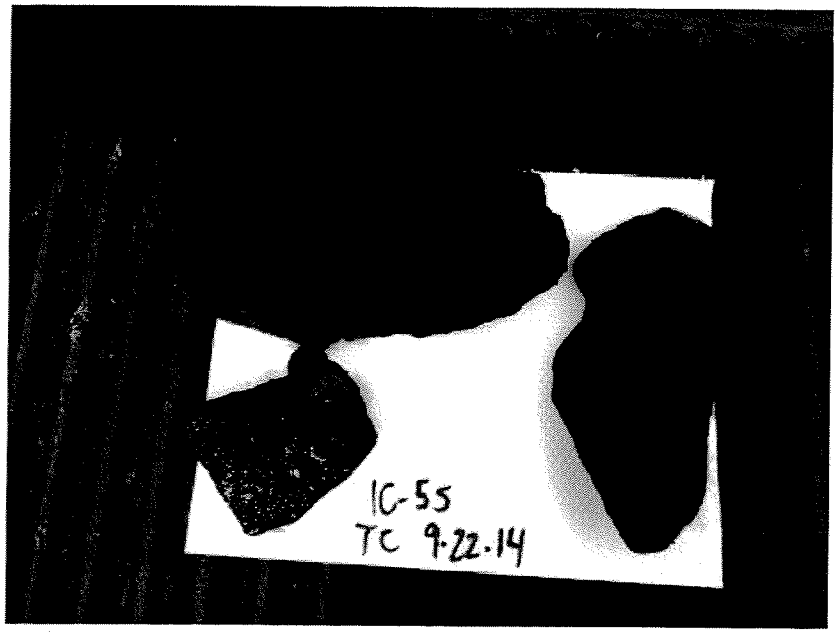
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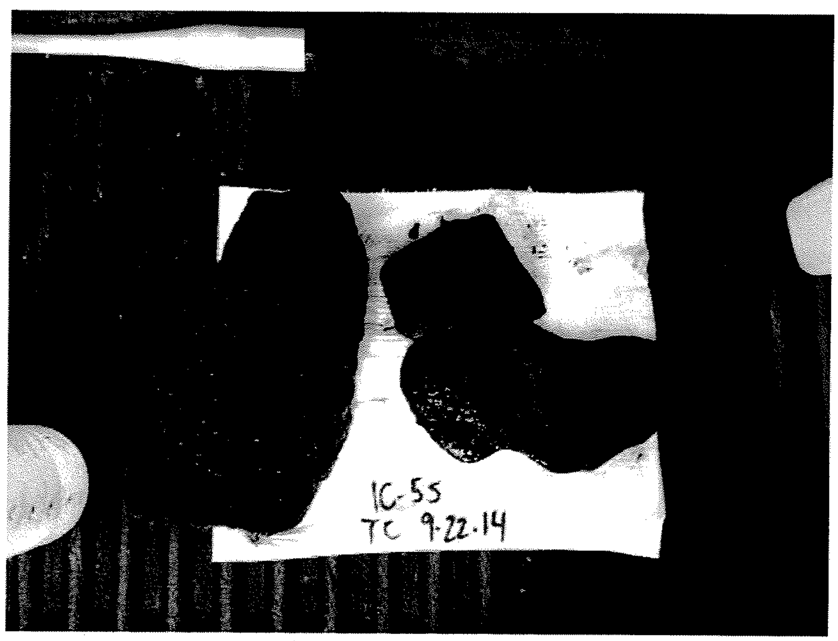

IC-55
TC 9-22-14

Exhibit 2

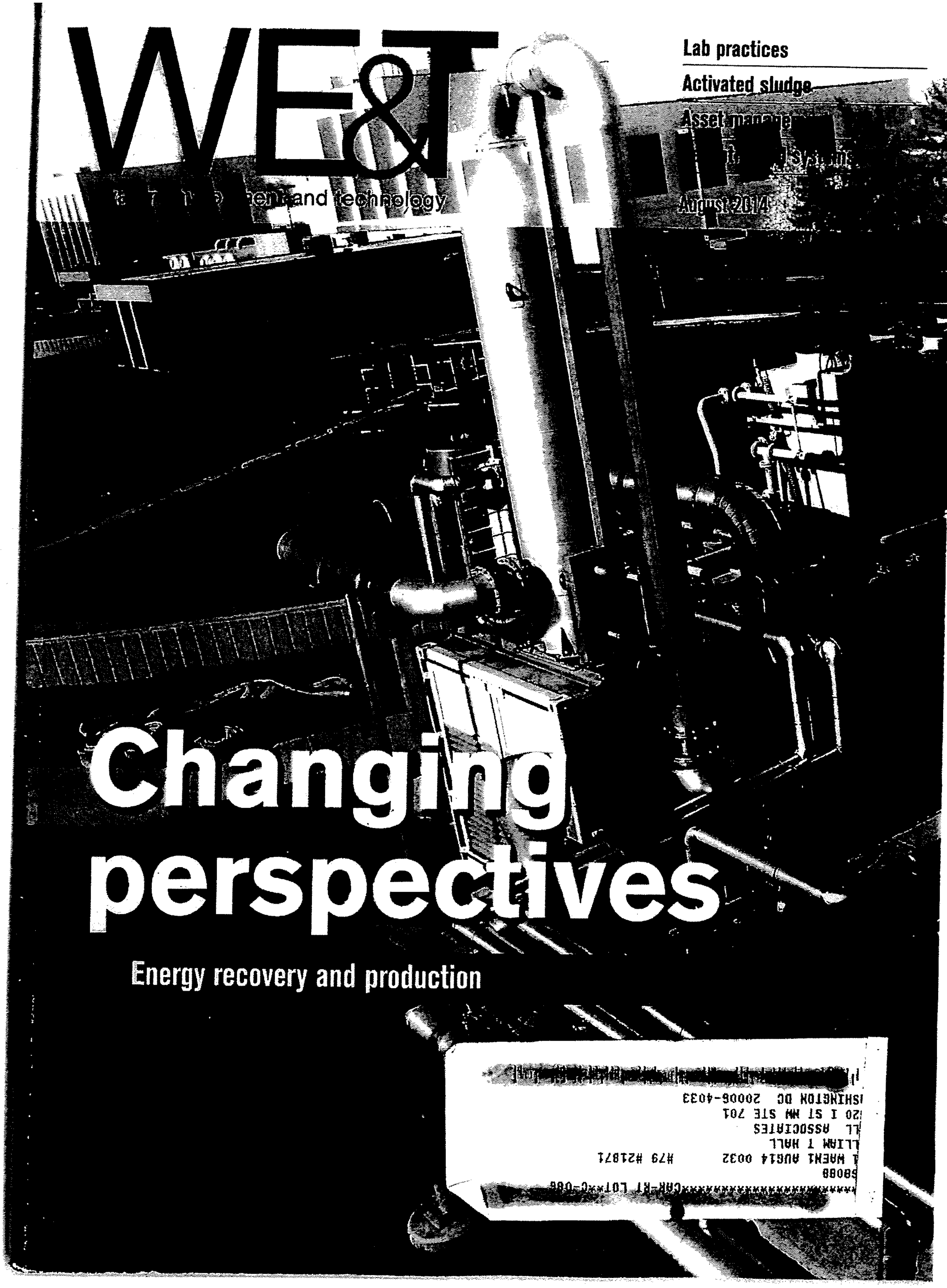
Nutrient Effect on Periphyton Growth in Streams

Citation	Parameter	Duration	Endpoint	Setting	Result
Bernhardt, E.S. & Likens, G.E. Controls on periphyton biomass in heterotrophic streams. Freshwater Biology. (2004). 49, 14-27.	N and P components, Light	21 days	Chl-a	10 streams in central New Hampshire	**Nutrients only stimulated periphyton biomass when added in combination with high light treatments.** Light and nutrient availability are both potentially important controls on periphyton growth. Experiment's nitrogen enrichment inhibited periphyton growth, reduced periphyton biomass on N diffusing substrates.
Bourassa, N., and A. Cattaneo. Control of Periphyton Biomass in Laurentian Streams (Quebec). Journal of the North American Benthological Society. Vol. 17(4) (Dec., 1998): 420 – 429	TP, TDP, Depth, Current, Light	2 months	Chl-a AFDM	12 streams	TP: 5 – 54 µg/L Chl-a: 5 – 55 mg/m^2 None of the variables explained a significant fraction of the variability in Chl-a. Grazer biomass was significantly correlated with TP, suggesting **nutrient effects on periphyton were obscured by grazing.**
Bourassa, N., and A. Cattaneo. Response of a lake outlet community to light and nutrient manipulation: effects on periphyton and invertebrate biomass and composition. Freshwater Biology. (2002). 44, 629-639.	TP, Light	80 days	Chl-a	Lake outlet in Montreal, Quebec	Enriched TP: 17-88 µg/L Enriched chl-a: 130 mg/m^2 Unenriched TP: 7-21 µg/L Unenriched chl-a: 90 mg/m^2 Periphyton biomass was, on average, 3 times higher in open than in shaded channels. Periphyton AFDM and chl-a were significantly affected by light, whereas the **effect of nutrient enrichment was not detectable.**

Citation	Parameter	Duration	Endpoint	Setting	Result
Bowes, M.J. et al. Nutrient and light limitation of periphyton in the River Thames: Implications for catchment management. Science of the Total Environment. (2012). 434: 201-212.	SRP, Light, N, Si	9 days	Chl-a	River Thames, England	SRP: 30-373 μg/L Chl-a: 9.4-14 $\mu g/cm^2$ A 60% increase in ambient SRP from 225 to 373 μg/L did not increase the rate of periphyton accrual. Reducing SRP to 171 μg/L also had no effect on the biomass of periphyton produced. Phosphorus limitation was only observed at SRP of 83 and 30 μg/L, but this only reduced periphyton biomass by 25%. Flumes in direct sunlight accrued significantly more periphyton than the shaded flumes. The fully shaded plumes (equivalent to full riparian tree canopy) reduced accrued periphyton biomass by 34 to 56% compared to full sunlight.
Figueroa-Nives, D, T. Royer, and M. David. Controls on chlorophyll-a in nutrient-rich agricultural streams in Illinois, USA. Hydrobiologia (2006) 568: 287 – 298.	SRP, TP Light Turbidity Scour	6 months	Chl-a (mg/m^2); AFDM	18 streams in watersheds dominated by row-crop ag.	SRP: 50 – 80 μg/L. Max Chl-a: 140 mg/m^2 Study shows benthic algal growth significantly higher in non-shaded sites and a significant relationship between chl-a and **turbidity**.
Greenwood, J. and A. Rosemond. Periphyton response to long-term nutrient enrichment in a shaded headwater stream. Can. J. Fish. Aquat. Sci. 62: 2033 – 2045 (2005)	SRP Light	2 years	Chl-a (mg/m^2); AFDM; Bio-vol.	Headwater Stream	Max Growth – 25 mg/m^2 during Spring <10 mg/m^2 during July-Sept. SRP – 45 – 51 μg/L (See, Fig 2 at 2037) **Illustrates effect of shading on growth.**
Hill, W., S. Fanta, and B. Roberts. Quantifying phosphorus and light effects in stream algae. Limnol. Oceanogr. 54(1), 2009, 368 - 380	SRP Light	13 days	Chl-a (mg/m^2); Bio-vol.	Artificial Stream	Max Growth – 150 mg/m^2 SRP – 12 μg/L (See, Fig 1 at 372) SRP – 25 μg/L (saturation conc.) **Algal growth strongly limited by inadequate light** (<2 mol photons/m^2/d) characteristic of moderately developed tree canopy

Citation	Parameter	Duration	Endpoint	Setting	Result
Hill, W. & S. Fanta. Phosphorus and light colimit periphyton growth at subsaturating irradiances. Freshwater Biology. (2008). 53, 215-225.	SRP, Light	1 day	Chl-a	Large flow-through lab streams	Growth rate plateaued at $\mu \approx 0.25$ above 22 µg/L SRP. **The relationship between periphyton growth and SRP conc. suggests nutrient SRP criteria ≥ 25 µg/L will do little to preclude stream eutrophication.**
Hill, W.R. & Knight, A.W. Nutrient and light limitation of algae in two northern California streams. Journal of Phycology. (1988). 24, 125-132.	NO_3, PO_4	31 days	Chl-a, AFDM	Second-order streams in N. Cali.	Chl-a and algal biovolume were 3 to 8 times greater at sites under gaps in tree canopy. At Fox Creek, nutrient enrichment had little positive effect on biomass accrual. Mean AFDM and algal biovolume were greatest on control substrates and the increase in chl-a on nitrate + phosphate substrates was small compared to the increase in biomass caused by openings in tree canopy.
Kiffney, P., and J. Bull. Factors controlling periphyton accrual during summer in headwater streams of Southwestern British Columbia, Canada. Journal of Freshwater Ecology, Vol. 15(3) – Sept, 2000	Phosphorus, Light, Grazers	6 weeks	Chl-a AFDM Accrual Rate	Natural streams; test stream has forested and clear sections	Natural levels of Phosphorus were low in all streams (**1.4 – 1.8 µg/L**). Study evaluated effect of shade and grazers on periphyton. Light was clearly a limiting factor (Chl-a **190 mg/m^2 in open stream**; < 50 mg/m^2 in canopied streams) (See, Fig 3 at 345)
Mallory, M.A. & Richardson, J.S. Complex interactions of light, nutrients and consumer density in a stream periphyton-grazer (tailed frog tadpoles) system. Journal of Animal Ecology. (2005). 74, 1020-1028.	N and P components, light	42 days	Chl-a, AFDM	Small, steep streams in coastal BC, Canada	SRP = 3 µg/L DIN = 4 µg/L Shade chl-a: 0.5-1.0 mg/cm^2 Light chl-a: 1.2-2.4 mg/cm^2 Chl-a abundance was 23-66% higher under light conditions than shade.

Exhibit 3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Mercury falling

How a facility upgrade intended to reduce algae growth resulted in unintended (yet favorable) consequences

Robert Brent, Ross Morland, David Berberich, Spencer Davis, Brandon Foltz, and Kurt Drummond

While most residents generally are concerned about the health of local rivers, lakes, and estuaries, often it is difficult for them to see the immediate benefits of costly facility upgrades, especially for a waterbody more than 480 km (300 mi) downstream. The City of Waynesboro, Va., faced this challenge when it upgraded the Waynesboro Wastewater Treatment Plant in 2010 to meet newly promulgated Virginia nutrient regulations for dischargers within the Chesapeake Bay watershed.

Waynesboro, a small city of about 20,000 nestled in the foothills of Virginia's Blue Ridge Mountains, is located on the South River, which forms the headwaters of the Shenandoah–Potomac River system, a major tributary to the Chesapeake Ba

To demonstrate that nutrient reductions aimed at reducing eutrophication in the bay also could improve local water qualit the city partnered with researchers from James Madison University (JMU; Harrisonburg, Va.) to study water quality improvements to the South River throughout the upgrades. While the main objective – to reduce algal growth – was not necessarily achieved, a surprising side benefit was the possibl reduction in methylmercury accumulation within this mercury-impaired stream.

◄ Five monitoring stations were set up on the South River upstream and downstream of the Waynesboro Wastewater Treatment Plant discharge point. Dissolved oxygen, pH, conductivity, temperature, chloride, nitrate, sulfate, total phosphorus, filtered and unfiltered total mercury, and filtered and unfiltered methylmercury were measured.
Robert Brent

The need to reduce nutrients dramatically

Virginia nutrient regulations required that the water resource recovery facility (WRRF) reduce annual nitrogen loads to 22,103 kg (48,729 lb) and annual phosphorus loads to 1658 kg (3655 lb) by January 2011. This meant that the facility would need to reduce loads by 65% and 88%, respectively. To meet the new regulations, the city replaced trickling filters and rotating biological contactors with a five-stage Bardenpho biological nutrient removal (BNR) process and denitrification filters. In addition, the facility was expanded from 15,000 m^3/d (4 mgd) to accommodate a 23,000-m^3/d (6-mgd) design flow, new secondary clarifiers were constructed, disinfection was upgraded, and a solids dewatering facility was added.

The upgrades and BNR installation at the WRRF were effective, at least from a treatment perspective. Prior to the upgrades, total nitrogen levels in effluent averaged 17 mg/L, while total phosphorus levels averaged 4 mg/L. Within 1 year of the upgrades, nutrient levels dropped dramatically (see Figure 1, below). By 2011, average total nitrogen levels dropped to 1.17 mg/L, and phosphorus levels dropped to 0.12 mg/L – reductions of 93% and 97%, respectively. Annual loads similarly were reduced, and the city met Chesapeake Bay nutrient regulations with nitrogen and phosphorus loads of 4879 kg (10,756 lb) and 350 kg (771 lb), respectively, in 2011.

Upgrade effects on algal growth and mercury uptake

While the upgrades at the WRRF primarily were intended to meet Chesapeake Bay watershed goals, the upgrades likely also would improve local water quality in the South River. To quantify those improvements, JMU researchers began a water quality study in 2010 that intensively monitored the river prior to, during, and after the upgrades.

The researchers established five monitoring stations on the South River: 0.40 km (0.25 mi) upstream from the WRRF discharge and 0.2, 0.8, 2, and 16 km (0.1, 0.5, 1.2, and 10 mi) downstream from the discharge point (see Figure 2, p. 64). At each station, the following water quality parameters were measured: dissolved oxygen, pH, conductivity, temperature, chloride, nitrate, sulfate, total phosphorus, filtered and unfiltered total mercury, and filtered and unfiltered methylmercury.

In addition, the JMU team measured the growth of algae in the river and the uptake of mercury by the algae. Algal growth is a direct measure of nutrient enrichment, so algal growth rates would presumably decrease with reduced nutrient loads. There also was a possibility that nutrient reductions could affect the cycling of mercury, a long-term contaminant in the river. Legacy industrial sources had polluted the river with mercury decades ago, and sport fish, like smallmouth bass, continue to exceed safe mercury levels for human consumption.

The cycle of mercury accumulation in the river begins with inorganic mercury being transformed to the more bioavailable methylmercury form under low oxygen conditions. Methylmercury is then taken up by algae and transferred up the food chain to invertebrates, to small forage fish, and then to top predators such as smallmouth bass. Nutrient reductions in the river could raise dissolved oxygen levels and lower mercury methylation rates, resulting in lower mercury levels at each link in the South River food chain.

To measure algae growth and mercury uptake, the JMU team placed eight baskets of clean rocks at each monitoring location. Algae were allowed to colonize the rocks and grow for 6 weeks. At 2, 4, and 6 weeks of colonization, the rocks were removed and a defined area was scraped to remove the colonized algae. Algae samples were dried, weighed, and ashed at 500°C to determine biomass. A second batch of 6-week samples were scraped from the rocks and analyzed for mercury and methylmercury content.

Nutrient results

As stated earlier, the BNR upgrades were highly successful in reducing nutrients in the discharge. These reductions also affected nutrient levels in the South River (see Figure 3, p. 65). South River phosphorus levels decreased within a range of 85% to 94% downstream of the outfall. Reductions in nitrogen concentrations, however, were not as dramatic. Nitrate levels downstream of the outfall dropped in a range of 39% to 59%.

Nonpoint sources of nitrogen in the watershed explained the smaller reductions observed for instream nitrate levels. Prior to upgrades, the Waynesboro facility outfall contributed approximately

Figure 1. Nutrient reductions in Waynesboro facility discharge

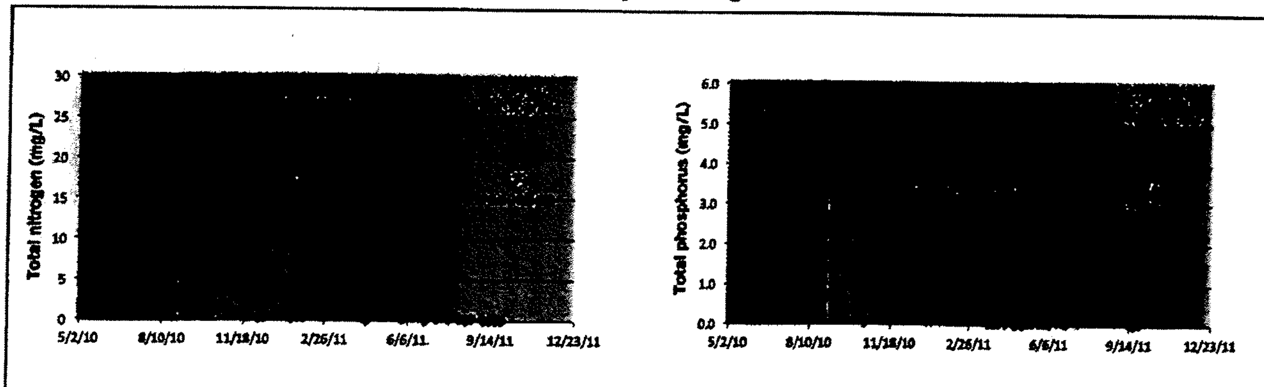
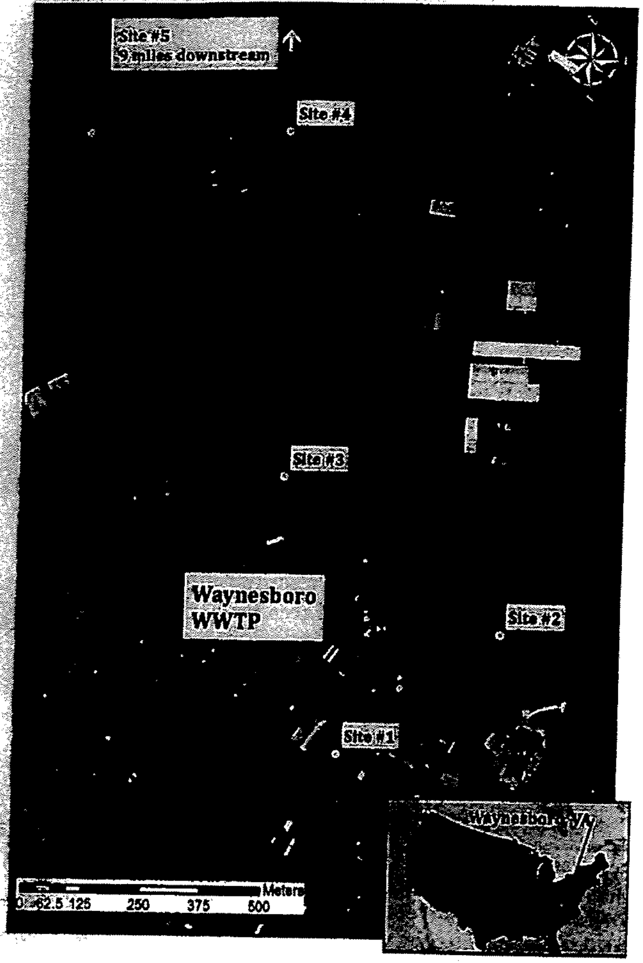


Figure 2. Location of Waynesboro monitoring sites



93% of the instream phosphorus load at that point in the South River. However, for nitrogen, the facility discharge accounted for a smaller fraction of instream loads (63%).

Other instream water quality indicators showed no consistent or significant trends resulting from the upgrades. Conductivity and temperature varied by season but were relatively unaffected by the upgrades. Chloride, sulfate, and pH were unchanged. Dissolved oxygen conditions within the river improved somewhat, but diurnal variations made it difficult to determine whether these improvements were significant and resulted from the upgrades.

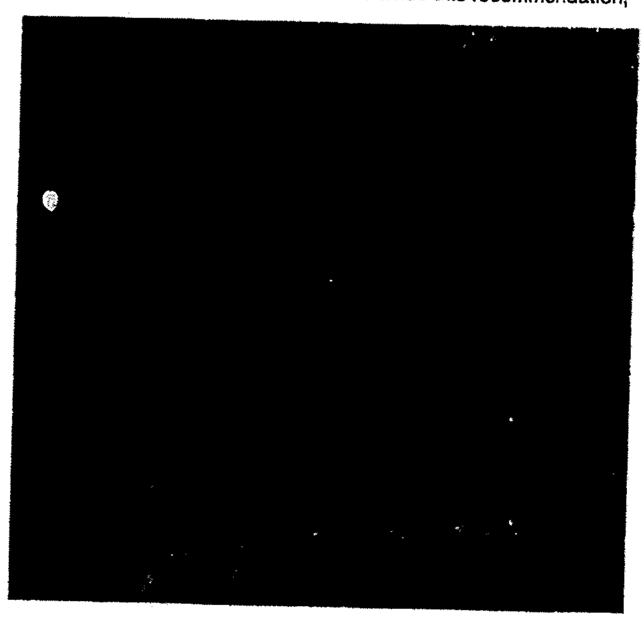
Algae growth increases despite nutrient reductions

Algal growth did not decrease significantly after the upgrades at any of the locations (see Figure 4, p. 65). In fact, at one site located 0.8 km (0.5 mi) from the outfall, algal growth increased significantly, nearly doubling from 1.2 to 2.1 mg/cm^2.

The reason was not definitively identified. It is possible that while overall nitrogen levels decreased in effluent, more reduced nitrogen in the form of nitrite or ammonia was available directly downstream. Since ammonia is a more readily available nitrogen source for algae growth than nitrate, this could have spurred algal growth for a short distance downstream until reduced forms were oxidized to nitrate.

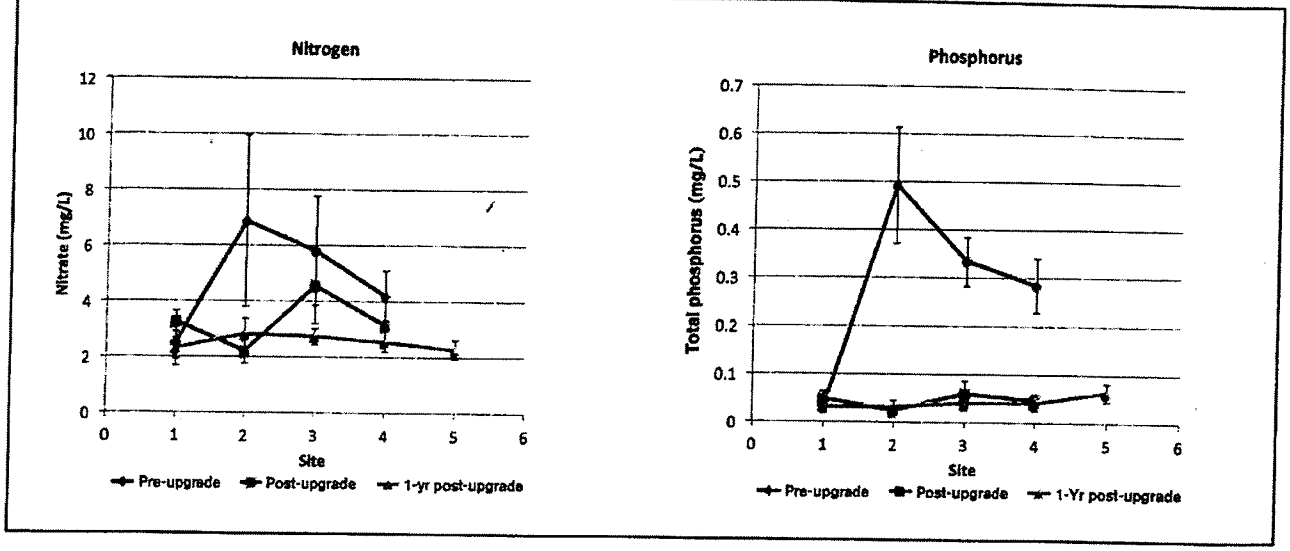
Research assistants Brandon Foltz and Kurt Drummond sample algae on rocks from the South River. Robert Brent

The finding that algal growth had not decreased after the upgrades is interesting. The purpose of nutrient regulations in the Chesapeake Bay watershed is to reduce algae growth and improve water quality in the bay. However, even at a local scale, large nutrient reductions (greater than 90%) were not effective in limiting algae growth. Certainly, Waynesboro's lower nutrient loads will be multiplied by reductions from other point sources throughout the watershed, but the ultimate fate of the bay may rest in the hands of nonpoint nutrient sources. In the South River, even when the primary phosphorus source (Waynesboro facility) was reduced by 97% and instream levels were reduced 94%, algae growth was not reduced. This is because remaining nutrient levels in the river from point source residuals and nonpoint sources have yet to reach critical thresholds. The U.S. Environmental Protection Agency's recommended nutrient criteria for this ecoregion are 0.01 mg/L phosphorus and 0.31 mg/L nitrogen. Even after upgrades, average nitrogen levels in the South River were twice this recommendation,



Baskets of clean rocks were used to colonize algae in the South River for biomass and mercury analysis. Robert Brent

Figure 3. Nutrient reductions in the South River resulting from facility upgrades



and phosphorus levels were 3 to 4 times higher than the recommended level. To meet both local water quality goals and Chesapeake Bay watershed goals, significant help is needed from the nonpoint source community.

Mercury uptake results promising

To evaluate the effects of nutrient upgrades on mercury cycling, methylmercury concentrations in algae at each time period and location were normalized against the upstream control site (Site 1).

Normalized methylmercury concentrations in algae downstream of the Waynesboro outfall decreased significantly after the upgrades (see Figure 5, below), ranging from 44% to 81% in downstream stations. This indicates that as nutrient loads decrease, the rate of mercury methylation slows down, reducing the amount of bioavailable mercury. This added benefit, which was not intended as a part of the Waynesboro facility upgrades, may be one of the most beneficial outcomes of the upgrades.

The City of Waynesboro spent $32 million on upgrades aimed at reducing nutrients in the Chesapeake Bay. The upgrades were extremely successful in reducing nitrogen and phosphorus in the discharge and in the receiving stream, the South River. But these large nutrient reductions did not translate into reduced algal growth in the river.

Still, perhaps the most surprising finding from the study was that the nutrient reductions might help to improve mercury contamination issues in the river. Large reductions in mercury loadings from the former industrial site and the watershed will still be needed to reach safe fish consumption goals, but the effect of nutrient reductions on mercury dynamics may help to reach this goal sooner.

Robert Brent *is an associate professor at James Madison University (Harrisonburg, Va.). At the time this project was conducted,* ***David Berberich, Spencer Davis, Brandon Foltz,*** *and* ***Kurt Drummond*** *were undergraduate research assistants at James Madison University.* ***Ross Morland*** *is the coordinator at the Waynesboro Wastewater Treatment Plant for the City of Waynesboro, Va.*

Figure 4. Algae growth downstream of the Waynesboro Wastewater Treatment Plant before and after upgrades

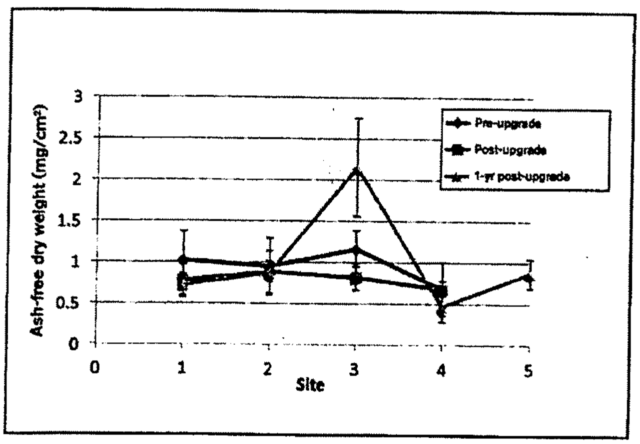


Figure 5. Mercury uptake in algae before and after upgrades